STAR

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER DRXTH-AS-IA-83A016	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Historical Overview of the Nike Missile System		5. TYPE OF REPORT & PERIOD COVERED Final
		6. PERFORMING ORG. REPORT NUMBER ESE-A016
7. AUTHOR(s) B.N. McMaster, J.B. Sosebee, W.G. Fraser, K.C. Govro, C.F. Jones, S.A. Grainger, and K.A. Civitarese		8. CONTRACT OR GRANT NUMBER(s) DAAK11-81-C-0093
9. PERFORMING ORGANIZATION NAME AND ADDRESS Environmental Science and Engineering, Inc. P.O. Box ESE Gainesville, Fla. 32602		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS N/A
11. CONTROLLING OFFICE NAME AND ADDRESS U.S. Army Toxic and Hazardous Materials Agency Assessments Division Aberdeen Proving Ground, Md. 21010		12. REPORT DATE December 1984
		13. NUMBER OF PAGES 146
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office) U.S. Army Toxic and Hazardous Materials Agency Assessments Division Aberdeen Proving Ground, Md. 21010		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE N/A

16. DISTRIBUTION STATEMENT (of this Report)

Distribution limited to U.S. Government Agencies only for protection of privileged information evaluating another command: September 1983. Other requests for this document must be referred to: Commander, U.S. Army Toxic and Hazardous Materials Agency, Aberdeen Proving Ground, Md. 21010.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

N/A

18. SUPPLEMENTARY NOTES

N/A

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

An assessment was conducted of former Nike missile sites to determine facilities present and operational procedures, particularly for material handling and disposal. The assessment relied on unclassified documents and interviews with Army personnel familiar with the sites and did not include site visits.

The Nike system was deployed between 1954 and the mid-1970s, with the Nike Hercules replacing the Nike Ajax in the early 1960s. The missile sites were

20. ABSTRACT (Continued)

generally deployed around major metropolitan areas and strategic military installations.

Normal operation of a Nike site included the use and onsite disposal of solvents, battery acid, fuel, and hydraulic fluid. Environmentally persistent compounds disposed of included carbon tetrachloride, trichloroethylene, trichloroethane, lead, and various hydrocarbons. In general, the propellants and warhead components were carefully controlled.

SUMMARY

Nike Ajax missiles were first deployed in 1954, and remained in use until 1964. The Ajax was a two-stage missile using a solid-fueled booster and a liquid-fueled sustainer motor to deliver high explosive warheads to a radar-determined intercept point with target aircraft.

Nike Hercules missiles were introduced in 1958, and gradually replaced the Ajax. Some Hercules missiles remained in use until the mid-1970s. Hercules was a two-stage missile which differed from Ajax in that the sustainer motor was solid-fueled, and the warheads were primarily nuclear.

The typical Nike battery consisted of two main operating areas and sometimes included a third area for housing. The battery control area contained the electronic equipment for target tracking, missile guidance, and fire control. Support facilities such as an electric generator building and motor pool were also included in some instances. The launch area contained the facilities and equipment required to assemble, test, and maintain the missiles and associated launchers. Motor pools, generator buildings, guard dog kennels, and other support facilities were also generally included in this area.

General operational procedures used at Nike sites were found to be consistent, although specifics of material handling and disposal varied considerably for individual batteries. The most common liquids disposed of onsite were solvents used in maintenance operations. These were routinely dumped into sumps where they soaked into the ground. Fuel components were also sometimes disposed of in this manner, but to a more limited extent. Only isolated incidents of containerized disposal were reported.

TABLE OF CONTENTS

TABLE OF CONTENTS
(Continued, Page 2 of 2)

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS AND ABBREVIATIONS

AAA	antiaircraft artillery
ABMA	U.S. Army Ballistic Missile Agency
ACQR	acquisition radar
ADSIMO	Air Defense Special Items Management Office
AMC	U.S. Army Materiel Command
AOMC	U.S. Army Ordnance Missile Command
ARAACOM	U.S. Army Antiaircraft Command
ARADCOM	U.S. Army Air Defense Command
ARGMA	U.S. Army Rocket and Guided Missile Agency
ATBM	antitactical ballistic missile
$atm \cdot m^3\ mole^{-1}$	atmosphere cubic meters per mole
BCA	battery control area
BN	battalion
BTRY	battery
^oC	degrees Celsius
cm	centimeters
COE	U.S. Army Corps of Engineers
CONAD	Continental Air Defense Command
CONUS	continental United States
DARCOM	U.S. Army Materiel Development and Readiness Command
EPA	U.S. Environmental Protection Agency
FTBL	Headquarters, U.S. Army Air Defense Center and Fort Bliss
gal	gallons
ha	hectares
HQ	headquarters
hr^{-1}	per hour
ICBM	intercontinental ballistic missile
IRFNA	inhibited red fuming nitric acid
kg	kilograms
km	kilometers
K_{oc}	sediment-water partition constant

K_{ow}	octanol-water partition constant
kph	kilometers per hour
kW	kilowatts
l	liters
LA	launch area
m	meters
m^3	cubic meters
mg/l	milligrams per liter
MICOM	U.S. Army Missile Command
$l\ cell^{-1}\ hr^{-1}$	milliliter per cell hour
$mole^{-1}\ hr^{-1}$	per mole hour
MTR	missile tracking radar
NAMSA	NATO Maintenance and Supply Agency
NATO	North Atlantic Treaty Organization
NIPDWR	National Interim Primary Drinking Water Regulations
NORAD	North American Air Defense Command
OCO	Office of Chief of Ordnance
PCBs	polychlorinated biphenyls
POL	petroleum, oils, and lubricants
R&D	research and development
torr	millimeters of mercury
TTR	target tracking radar
UDMH	unsymmetrical dimethyl hydrazine
ug/l	micrograms per liter
USAEHA	U.S. Army Environmental Hygiene Agency
USAF	U.S. Air Force
USATHAMA	U.S. Army Toxic and Hazardous Materials Agency
USN	U.S. Navy
WWII	World War II

1.0 INTRODUCTION

Between 1954 and the early 1970s, Nike Ajax and Nike Hercules missiles were deployed by the U.S. Army throughout the continental United States (CONUS) to protect major metropolitan areas and strategic military installations from aerial attack. Maintenance of the missile batteries in a combat-ready posture required the storage, handling, and disposal not only of missile components and propellants but also of solvents, fluids, fuels, and other materials required for a variety of support functions. The purpose of this report is to describe the Nike missile system and associated activities as they pertain to environmental concerns.

Information presented in this report was obtained from unclassified documents and from interviews with Army personnel who were assigned to Nike units (App. A). The documents included technical reports, unit histories, and field manuals. Published sources, however, presented an incomplete understanding of disposal practices and other topics of interest. Much of the information provided herein was obtained through extensive interviews with approximately 30 persons currently assigned to units at the U.S. Army Air Defense Center and Fort Bliss, Tex. (FTBL). Other agencies were also consulted (see App. A). The interviewees' experience with the Nike system spanned the entire period of missile deployment and included virtually every Nike site in CONUS. These persons were familiar with activation, deactivation, and conversion from Ajax to Hercules systems as well as with routine operations.

Detailed information is provided regarding the history, military organization, and physical components of the Ajax and Hercules systems. Development and testing of Nike Zeus is discussed briefly, as this system was never operationally deployed. Such information is intended to allow the report to be utilized as a "stand-alone" reference and to form the basis for certain inferred conclusions concerning environmental impacts of the system.

2.0 HISTORY OF THE NIKE PROGRAM

2.1 AJAX

Shortly after the end of World War II (WWII), the Army recognized the need for an air defense system capable of engaging high speed, maneuverable targets at far greater ranges than the conventional artillery available at the time. Development studies on such a system were begun as early as 1945. These studies led to establishment of a formal research and development (R&D) program for the system later to become known as Nike Ajax. After the Korean Conflict began in 1950, pressure to make the system operational mounted, and in late 1951, the Nike program was accelerated. The development and production processes were overlapped in order to advance the system to the tactical weapon stage as soon as possible. The program was originally called Nike I until November 1956, when it was renamed Nike Ajax.

ontractor evaluation tests of the tactical prototype Nike Ajax system began in January 1953 and continued through May of that year. The first prototype model battery was delivered to White Sands Proving Ground, on May 15, 1953. Service evaluation tests by tactical Army troops began in October 1953.

Major test locations for the Nike Ajax system were Redstone Arsenal, Ala.; FTBL; and the adjacent White Sands Missile Range, then known as White Sands Proving Ground. The system performed well in testing, and no major design changes were made once service evaluation testing began.

Conversion of the United States air defense system from artillery to guided missiles began in March 1954, when the first combat-ready Nike Ajax battalion was deployed at Fort Meade, Md., in what was then known as the Washington-Baltimore Defense Area. Conventional antiaircraft gun units were outnumbered by Nike Ajax units by December 1956, and the conversion to guided missiles was completed by mid-1958.

development of Nike Ajax missiles began with the designated defense areas around major cities on the United States east coast. These included Boston, Providence, Philadelphia-New York, and Baltimore-Washington. West coast sites were added soon after near Seattle, San F

Angeles. Before deployment was complete, additional sites were added at major military bases and other cities in the southeast and midwest including Miami, Cleveland, Milwaukee, and Detroit. App. B shows the dates of deployment and location of CONUS Nike sites.

During its term of service in the field, the Nike Ajax system remained essentially unchanged. The second generation Nike system, originally called Nike B and later named Nike Hercules, was under development even while Nike Ajax was still being deployed. Thus, all the Ajax batteries were essentially the same in design and construction, and no effort was made to update the Nike Ajax batteries once they were deployed. In-field changes were limited to minor equipment modifications to improve operational efficiency. Beginning in late 1958, selected Ajax batteries were converted to the Hercules system. This process is described in Sec. 6.0.

The Ajax/Hercules conversions which took place between 1958 and 1961 followed essentially the same pattern as the original Ajax deployment, beginning with major east coast metropolitan defense areas and spreading to the west and midwest.

Final phase out of Ajax batteries which were not converted to the Hercules system began in early 1962. This process took 2 years and was completed in early 1964, when the last CONUS Nike Ajax battery was deactivated. Six non-tactical Ajax systems were retained at FTBL (Cagle, 1959; 1973).

2.2 HERCULES

Even before deployment of the Nike Ajax, it was realized that the weapon system had performance limitations which would prevent it from engaging formations of high speed, high altitude aircraft which would soon be in use. Most critical was the limited resolution of the Ajax target tracking radar, which tended to wander between planes in a formation, resulting in the missile passing between two aircraft and detonating without causing any damage to the attackers. In 1952, the Ordnance Corps began feasibility studies of an improved air defense system which would be capable of countering anticipated aerial threats and could be modified to keep pace with advances in attack systems.

Preliminary design studies of the Nike Hercules system began in February 1953. Design guidelines for the Hercules missile called for maximum use of proven components from the Ajax program and stipulated that both missiles must be compatible with all sets of Nike ground and launching equipment. The primary role of the new system was to attack fast, high flying aircraft formations with a single atomic warhead. The system was to have an alternate conventional warhead for use against single aircraft or missiles.

The tactical version of the Hercules system evolved from several overlapping R&D and industrial programs between 1955 and 1959. During this period, the liquid propellant second stage motor used in the Ajax program was found to be impractical for use in Hercules. In 1956, design of a new, solid propellant second-stage was begun. Known as the XM-30, the new engine was flight tested in 1957, and by early 1958 liquid propellants were eliminated from the Hercules flight test program. Test firings and minor modifications of the system continued through 1960. The system as it existed at that time later became known as the Basic Hercules system to distinguish it from subsequent modifications.

Training of personnel began in 1956 and was conducted at the Ordnance Guided Missile School, Redstone Arsenal; and at the Operational Training Center, FTBL. Deployment of the Basic Hercules system began in June 1958, even while engineering tests continued at White Sands Proving Ground and Redstone Arsenal. Deployment of the Basic Hercules system within CONUS was completed in the fourth quarter of 1961. App. B shows the deployment dates and locations of CONUS Hercules sites.

Hercules deployment, while following the basic pattern of metropolitan defense areas established by Ajax, added several new cities and a number of major military bases to the system. In the final configuration, there was no significant difference in Hercules batteries at different locations or in converted sites as compared to new sites.

During its term of service in the field, the Nike Hercules system underwent numerous design modifications. As previously mentioned, the system as

improvement programs were subsequently executed to keep the system up to date. The first resulted in deployment of the Improved Hercules system beginning in 1961. The second produced the Hercules Antitactical Ballistic Missile (ATBM) system, which was first introduced in 1963. Both programs provided improved target tracking, guidance, and interception capabilities by modifying or replacing radar and electronics equipment. Neither produced any significant change in the missile or the battery configuration.

Not all Hercules batteries were retrofitted with the new equipment as it became available, due to budget limitations. The guidelines used provided for retrofitting of certain batteries within a group, based on the number of batteries in a particular defense area. Hence, the field deployment within a single area in 1962 may have included Ajax, Basic Hercules, and Improved Hercules batteries. App. C presents maps of the various Metropolitan Defense Areas showing battery sites as of 1968.

In 1962, the Army began transferring operation of certain Hercules batteries to National Guard Units. Shortly thereafter, deactivation began at numerous locations. By 1970, the Army had deactivated most CONUS Hercules sites. National Guard Units continued to maintain a few sites until the late 1970s. Some Nike Hercules equipment is still retained at FTBL for classroom and operational training of troops from other North Atlantic Treaty Organization (NATO) countries (Cagle, 1959; 1973). The last operational battery at FTBL was deactivated in March 1983.

2.3 ZEUS

Nike Zeus was the first missile developed in the United States that was designed to defend against intercontinental ballistic missiles (ICBM). It was conceived in the early 1950s, and R&D began in 1956. The first test firing of Nike Zeus occurred at White Sands Missile Range on Aug. 26, 1959. The test was unsuccessful, however, since a booster fin failed several seconds after liftoff, causing an abnormally high angle of attack resulting in the rupture of the booster and the breakup of the missile. In October of the same year, Zeus was successfully fired at White Sands. In 1962, Zeus intercepted a Nike Hercules target. Reportedly, the Army installed a complete Nike Zeus complex at Kwajalein Island in the Pacific for full

capability tests against missile targets (Parson, 1962; Secretary of Defense, 1959). Zeus was never approved for production or deployment as a tactical system. However, the basic design concepts used in Zeus were incorporated into later, more sophisticated ATBM systems.

3.0 MILITARY ORGANIZATION OF THE NIKE MISSILE SYSTEM

3.1 NATIONAL AIR DEFENSE ORGANIZATION

The development of a missile-based air defense system was paralleled by changes in command structure and defense organization, beginning in July 1950, when the Army placed all artillery units with continental air defense missions under the newly organized U.S. Army Antiaircraft Command (ARAACOM) at Ent Air Force Base in Colorado Springs, Colo. The installation of Nike Ajax batteries in CONUS and overseas in 1953 led to further reorganization of the continental air defense structure and the Army's antiaircraft missions and organization. On Sept. 1, 1954, ARAACOM and corresponding elements in the U.S. Air Force (USAF) and U.S. Navy (USN) were combined to form the Continental Air Defense Command (CONAD) at Colorado Springs under the direction of the Joint Chiefs of Staff. In 1957, the Army's air defense responsibility within CONAD was defined as point air defense by missiles fired from the ground to aerial targets not more than 161 kilometers (km) away. Point defense was to include "geographical areas, cities, and vital installations that could be defended by missile units which received their guidance information from radars near the launching site" and also was to include responsibility of a ground commander for air protection of his forces. To represent this expanded, all-missile role more clearly, ARAACOM was redesignated the U.S. Army Air Defense Command (ARADCOM) on Mar. 21, 1957.

Further development on a national scale occurred in September 1957, when the North American Air Defense Command (NORAD) was formed to combine air defense capabilities of Canada and the United States under one Commander in Chief, who also headed CONAD. Like CONAD, NORAD elements in the United States reported directly to the Joint Chiefs of Staff. All Army ARADCOM units were placed under the operational control of NORAD (Cagle, 1973). App. D contains maps of geographic areas of responsibility for ARAACOM, ARADCOM, and NORAD for the period 1950 to 1973.

3.2 NIKE SYSTEM ORGANIZATION

During the period 1945 to 1951, R&D on the Nike program was directed by the Office of Chief of Ordnance (OCO). In 1951, OCO transferred to Redstone

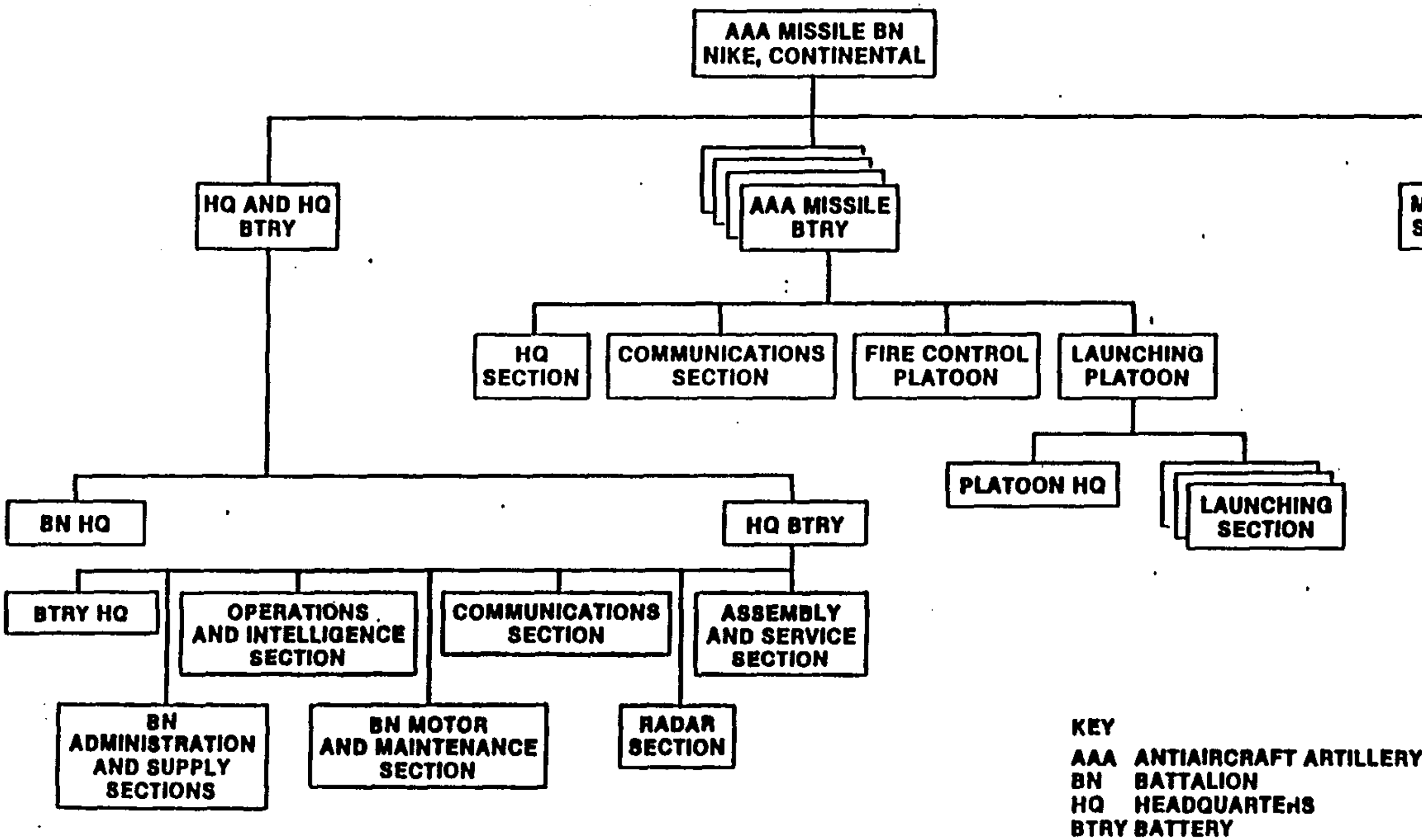
Arsenal, Ala., responsibilities relating to monitoring, coordinating, and conducting technical aspects of the program, particularly contractor-government coordination. OCO retained responsibility for general direction and decision making on policy, scope, objectives, and major modifications to missile design, performance, and operation.

In March 1958, prior to the deployment of the first Nike Hercules battery (June 1958), the U.S. Army Ordnance Missile Command (AOMC) was established at Redstone Arsenal. Subsidiary activities under the direction of AOMC included the Army Rocket and Guided Missile Agency (ARGMA), the U.S. Army Ballistic Missile Agency (ABMA), the Jet Propulsion Laboratory, White Sands Proving Ground, and Redstone Arsenal. ARGMA assumed responsibility for Nike Hercules from Redstone. Under the command of AOMC, ARGMA guided the Nike program through deployment of the Basic Hercules system and the subsequent Improved Hercules system, initial development of the ATBM Hercules system, and final conversion of Ajax systems to Hercules systems.

In 1961, both ARGMA and ABMA were disbanded. Two new missile systems groups were created under AOMC, one for ballistic missiles and one for guided missiles. Responsibility for the Nike program was assigned to the latter group. In 1962, further Army reorganization led to the establishment of two new commands: the U.S. Army Materiel Command (AMC), which replaced OCO, and the U.S. Army Missile Command (MICOM), which replaced AOMC. MICOM exercised control over Nike Hercules until system development ended in 1971. At that time, responsibility for Hercules fell to the Air Defense Special Items Management Office (ADSIMO), a small management office under MICOM (Cagle, 1973).

3.3 NIKE BATTALION ORGANIZATION

The basic operational unit of the Nike missile system was the fire unit, or launching section, composed of a control station and four launchers. In general, three firing units made up a battery, and four batteries formed a battalion. Fig. 3.3-1 depicts the organization of a typical Nike battalion,



SOURCE: U.S. Army, 1956.

Figure 3.3-1
ORGANIZATION OF A TYPICAL NIKE BATTALION

Prepared for:
U.S. Army Toxic and Hazardous Materials Agency
Aberdeen Proving Ground, Maryland

which consisted of a headquarters and headquarters battery, four firing batteries, and a medical section (U.S. Army, 1956). In the case of Nike Ajax, the battalion was operated by over 400 personnel, who typically handled 48 launchers and associated equipment (Ordway and Wakeford, 1960).

The headquarters and headquarters battery was composed of the battalion headquarters and the headquarters battery, which, in turn, comprised the following seven elements: (1) battery headquarters, (2) battalion administration and supply section, (3) operations and intelligence section, (4) battalion motor maintenance section, (5) communications section, (6) radar section, and (7) assembly and service section. The assembly and service section was a team of technical experts who supervised and assisted in the assembly, testing, and performance of organizational maintenance on missiles and boosters.

A missile battery was composed of six elements. These are listed below, followed by brief mission statements:

1. Headquarters Section: The responsibility of the headquarters section was essentially the operational and administrative control of personnel and equipment.
2. Communications Section: This section was responsible for installing and maintaining noncommercial communication nets and operating the commercial communication nets within the battery.
3. Fire Control Platoon: The fire control platoon was responsible for the operation and maintenance of the fire control equipment in the battery control area.
4. Launching Platoon: The launching platoon consisted of one launching platoon headquarters and three launching sections.
5. Launching Platoon Headquarters: The launching platoon headquarters which was responsible for the operation and training of the three launching sections, contained personnel who assembled, tested, and performed organizational maintenance on the Nike missile and maintained the rounds at the launching section.

6. <u>Launching Section:</u> The three launching sections were responsible for the preparation of the missile and booster for firing after they were delivered to the launching section from the assembly and test area. In addition, they performed routine nontechnical tests, checks, adjustments, and organizational maintenance (U.S. Army, 1956).

4.0 DESCRIPTION OF BATTERIES

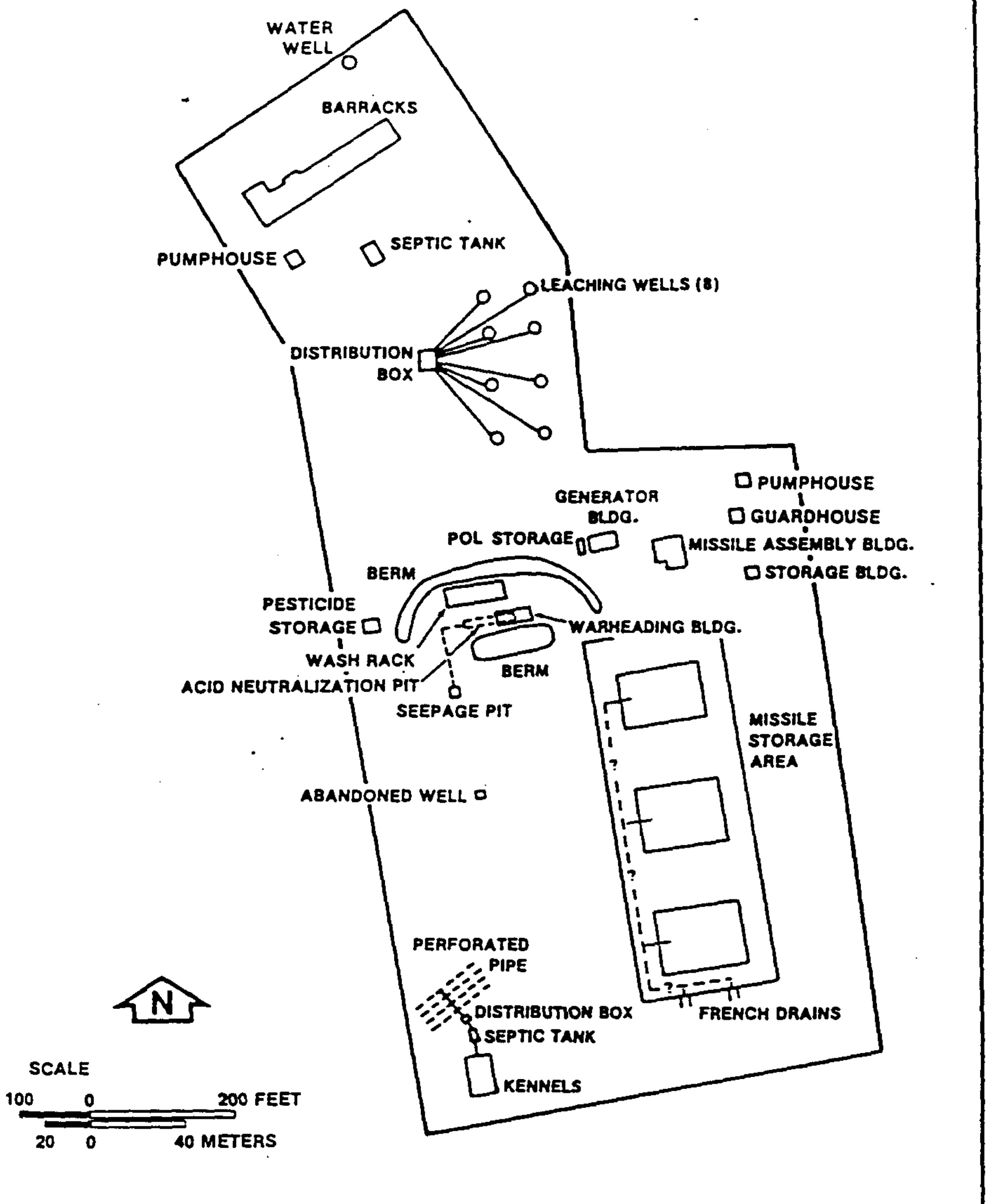
4.1 LAND USE

A typical Nike site consisted of two parcels of land. One parcel, the battery control area, was generally about 5 hectares (ha), while the other, the launch area, may have ranged in size from 15 to 30 ha. In some cases, a third parcel, the housing area, was included, adding 10 to 30 ha to the total. The two main areas, which had specific functions relating to battery operation, are discussed below. Equipment limitations dictated these areas could be no closer than 900 meters (m) from each other and no farther than 4.8 km.

The physical arrangement of structures within each area seems to have been site-specific, and no "standard" layouts were encountered. Figs. 4.1-1 and 4.1-2 illustrate the layout of one Nike site which included facilities that were reportedly common to most batteries, such as a motor pool, generator building, acid pit, and missile assembly buildings. Maps of additional sites are included in App. E. This particular site also included more uncommon features such as septic tanks with infiltration wells for liquid waste disposal, a blast protective berm around the warheading area, and barracks in the two operating areas. This indicates the extent to which site-specific methods were found to provide needed services and to make use of available property.

4.2 FUNCTIONS AND FACILITIES OF MAJOR AREAS

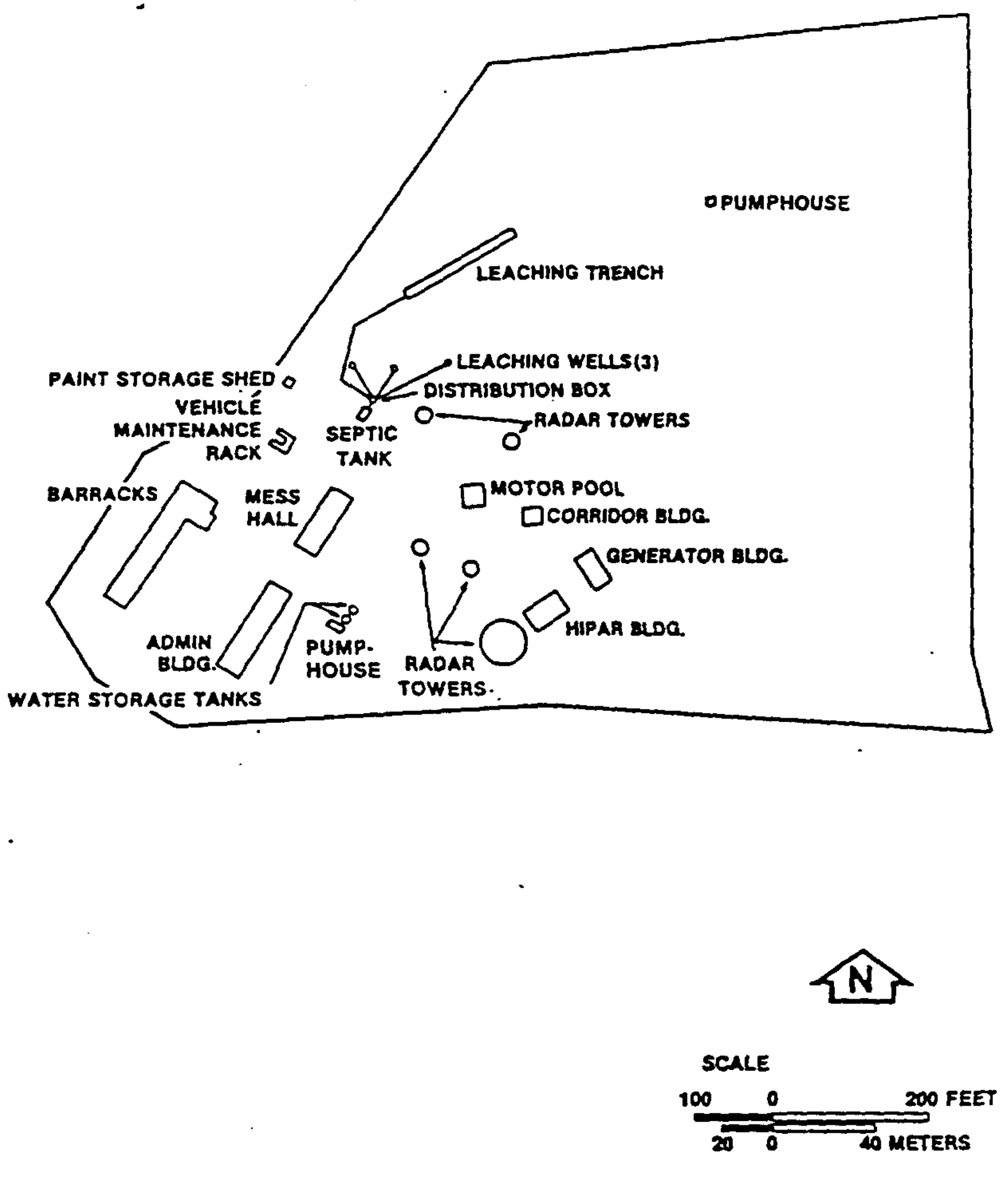
The battery control area at a Nike site contained all the radar, guidance, electronic, and communications equipment needed to identify incoming targets, launch missiles, and direct missiles in flight. This equipment included a computer used to determine an intercept point and guide the missile there. The target was identified by acquisition radar (ACQR) and then transferred to target tracking radar (TTR), which tracked the target to the intercept point. Once the battery commander issued the fire command and the missile was in flight, steering and burst orders were transmitted through the missile tracking radar (MTR). These different pieces of equipment were housed in mobile trailers and interconnected with communication cables.



SOURCE: ESE. 1983.

Figure 4.1-1
LAUNCH CONTROL AREA MAP
PHOENIX MILITARY RESERVATION (BA-03)
JACKSONVILLE, MD.

Prepared for:
U.S. Army Toxic and Hazardous Materials Agency
Aberdeen Proving Ground, Maryland



SOURCE: ESE, 1983.

Figure 4.1-2
BATTERY CONTROL AREA MAP
PHOENIX MILITARY RESERVATION (BA-03)
JACKSONVILLE, MD.

Prepared for:
U.S. Army Toxic and Hazardous Materials Agency
Aberdeen Proving Ground, Maryland

The missiles and warheads were assembled, serviced, checked, and fired at the launch area of a Nike Ajax site. In general, this area was subdivided into specific locations which were suitably equipped for specific operations. Missiles arrived at the launch site partially disassembled, unarmed, and, in the case of liquid-fueled stages, defueled. All the operations necessary to make the missile flight-ready were conducted in the launch area. Missiles were generally stored in an underground magazine and moved to the launchers by a rail and elevator system, although in some locations, surface storage facilities were used. A single battery included 12 launchers, divided into 3 groups of 4. A full complement of missiles included 1 missile in position and 3 reloads for each launcher (a total of 48 missiles). Because of limitations in the tracking and guidance systems, only 1 missile could be in flight at a time. Since the average flight time was 1 minute, a battery's full complement could be expended in less than 1 hour if the maximum rate of fire were sustained.

Most organizational-level maintenance was conducted in the launch area, which generally included the motor pool and generator buildings in addition to the defuel/refuel facilities. The motor pool and generator buildings were generally equipped with a sump which was routinely used for disposal of the oil, solvents, and paints used in equipment maintenance. These sumps were typically 1 to 2 cubic meter (m^3) excavated pits backfilled with gravel where liquids were simply dumped and allowed to soak into the ground. In some cases, the associated maintenance area had a drain consisting of a concrete trough covered with a metal grate. These drains were designed to carry any liquid spilled in the motor pool or generator area to the sump. This reportedly included sizeable quantities of diesel fuel, since the generator design made spillage during filling likely. Many Ajax batteries had an additional rock-filled pit in the defuel/refuel area used for disposal of inhibited red fuming nitric acid (IRFNA).

At some locations, holding tanks were used for temporary storage of liquid waste as an alternative to onsite disposal. The liquids collected were periodically pumped out for offsite disposal or recycling. This process was widely used to dispose of waste oils, and was sometimes employed for handling a variety of liquids.

The underground magazines included floor drains which routed any liquid to a sump normally located below the missile elevator shaft. These sumps were usually equipped with level-controlled pumps that transferred accumulated liquid to surface drainageways.

The third major area sometimes included at Nike sites was housing area. There was wide variation in the housing arrangements at different sites. In some cases, housing was in a different location than either of the two operating areas. In some cases it was contiguous to one operating area, or possibly split between the two. At locations where it was available, many personnel used nearby commercial housing.

Fuel storage tanks were a normal component of the operating areas. Total onsite storage ranged as high as 24,000 liters (1) and included fuel oil, diesel fuel, and gasoline. It was reported that most bulk storage was in underground tanks, although aboveground tanks, mobile tanks, and drum storage were also used.

4.3 OUTSIDE SUPPORT REQUIREMENTS

During normal daily operations, Nike sites used commercial electrical supplies where they were available. Transformers used in the electrical distribution system may have contained or been contaminated with polychlorinated biphenyls (PCBs), although records confirming this possibility were not located. The generators included in battery equipment were used for standby and emergency power. They were run under full load at intervals to ensure readiness in the event that commercial supplies were disrupted.

Water supplies for most batteries were obtained from municipal sources. For more remote sites, wells were used. In one instance well water was reportedly used for non-potable uses, and drinking water was trucked to the site. If municipal sewers were available, they were used to dispose of wastewater. Where such service was not available, septic tanks, oxidation ponds, or package treatment plants were used.

Solid waste generated at Nike facilities was disposed of through a variety of means. Often, the unit would have an agreement with a municipality for use of a public landfill. Very few of the Nike sites included an operational landfill. Numerous instances were reported that where convenient, open areas on or near the site were used for dumping of any and all waste. During deactivation, excess supplies (including solvents and paints which might be on hand but not shown on property records or otherwise accounted for) were routinely dumped at such sites as an expedient method of "balancing the books" before final site closure.

Buildings at most sites were heated by small oil-burning boilers. The fuel for these boilers was a major part of the petroleum, oils, and lubricants (POL) stored onsite. Reportedly, some sites in Alaska used turbine-type space heaters fueled with JP-4 in place of the oil-fired units.

5.0 DESCRIPTION OF THE NIKE MISSILES AND EQUIPMENT

5.1 AJAX

5.1.1 CONSTRUCTION

Nike Ajax was a 2-stage, supersonic missile armed with three large-radius, spherical-burst, high-explosive warheads mounted in the nose, center, and aft sections of the missile. The first stage was powered by a solid-propellant booster. The initial booster design included a cluster of four solid-propellant rockets with large fins. At the production stage, however, the design was modified to provide more rapid guidance response by means of a single, small-finned booster. In the second stage, the missile was powered by a liquid-fueled sustainer motor. The missile itself displayed three sets of cross-shaped fins in addition to those on the booster. The forward set was for steerage, the middle set may have been used for sensing, while the rear set provided stability (Burgess, 1957). Construction and performance data for the Nike Ajax missile are summarized in Table 5.1-1, and a schematic diagram of the basic missile configuration is shown in Fig. 5.1-1.

To control flight and engage the warheads, Nike Ajax used a guidance system coordinated with radar units on the ground. The guidance equipment was located within the cylindrical missile casing, along with the fuel tanks and ignition mechanism. The ACQR initially identified the target and alerted the battery control area, where the TTR picked up the target at close range and tracked it throughout the engagement. The third radar, the MTR, locked onto the missile prior to firing and tracked it throughout its flight. The two tracking radars fed target and missile present position data into a computer located in the battery control trailer. The computer then determined a predicted point of interception and issued steering orders to guide the missile to that point. At the optimum time, the computer issued a burst order which detonated the three warheads simultaneously, destroying the target. This process is depicted in Fig. 5.1-2 (U.S. Army, 1956; Ordway and Wakeford, 1960).

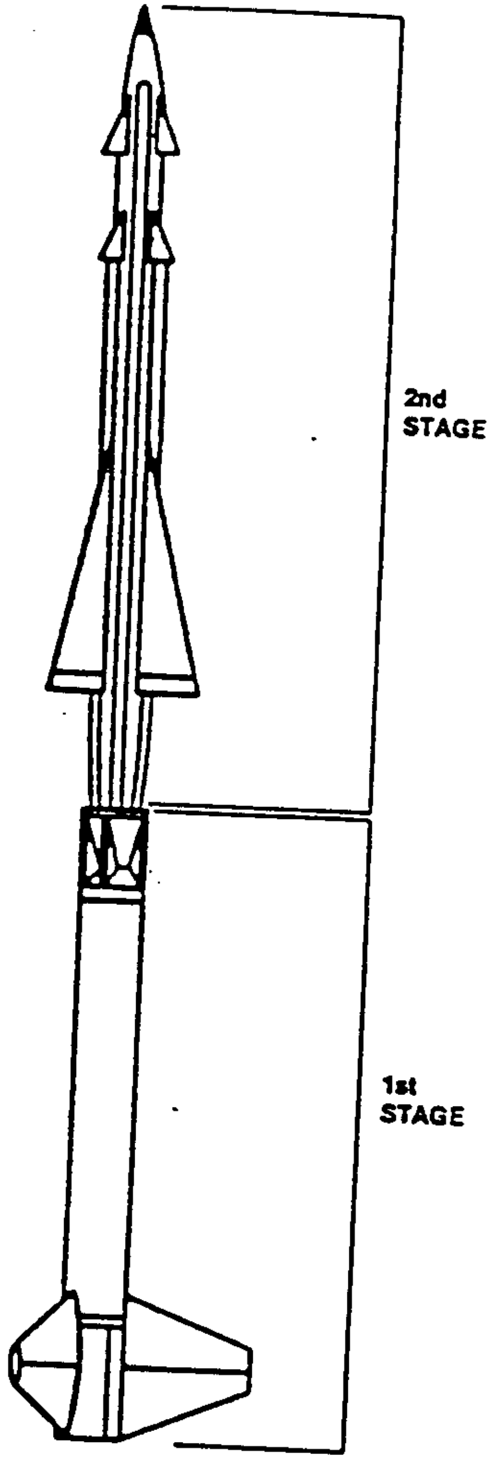
The Ajax was launched by remote control from a nearly vertical position. The entire missile system (consisting of the launcher, ACQR and TTR, and

Table 5.1-1. General Construction and Performance Data for the Nike Ajax

Characteristic*	Specification
Length (m)	6.4 (10.8 with booster)
Diameter (cm)	30.5 (booster, 40.6)
Weight (kg)	
Loaded	1,114.6
Payload	136.2
Range (km)	·40.25
Altitude (km)	16.1 - 19.2
Velocity (maximum in kph)	2,400
Sustainer Thrust (kg)	1,180.4
Sustainer Firing Time (seconds)	30
Sustainer Propellants	Nitric Acid and JP-4
Booster Propellant	Solid

* m = meters
cm = centimeters
kg = kilograms
km = kilometers
kph = kilometers per hour

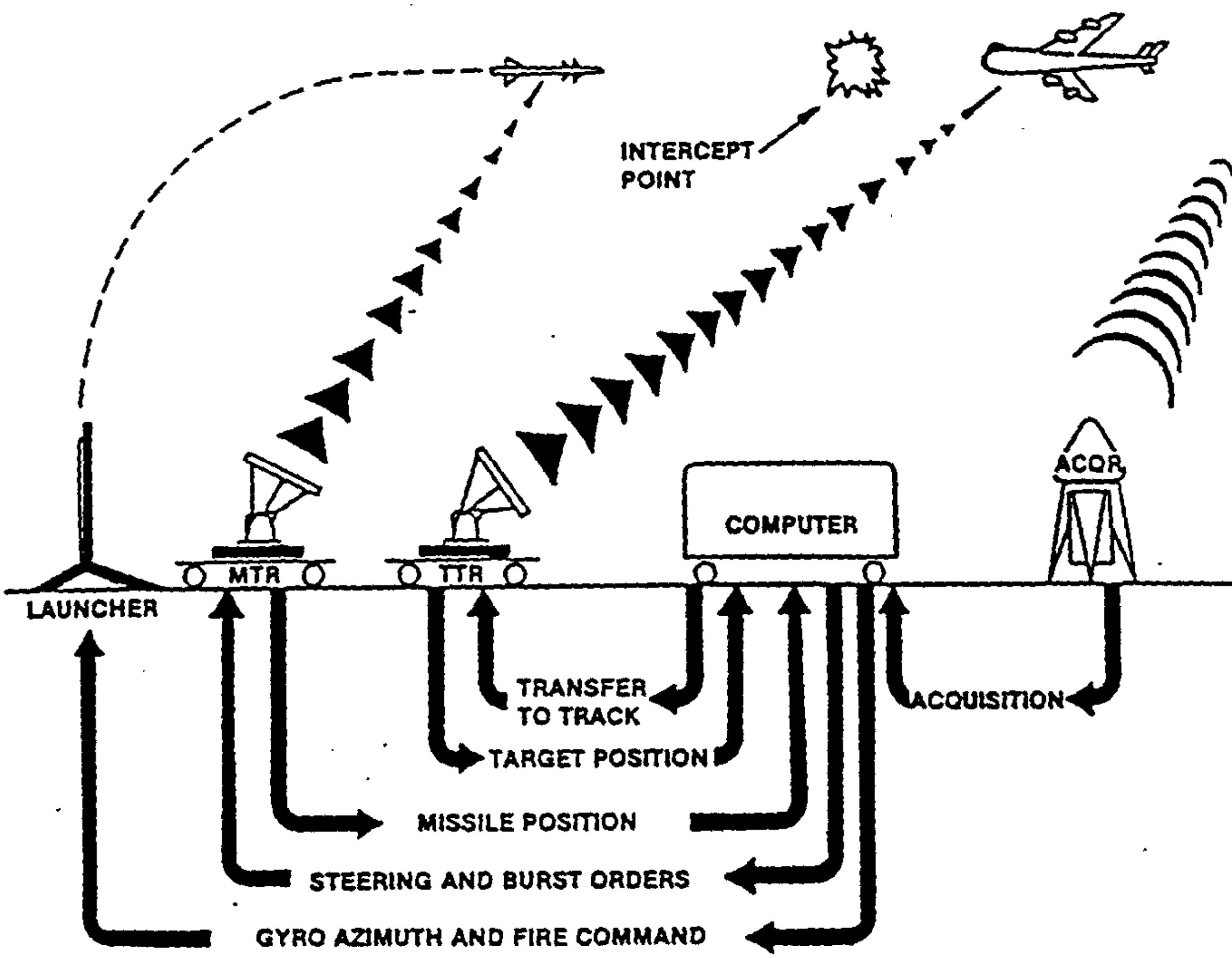
Source: Modified from Ordway and Wakeford, 1960.



SOURCE: Ordway and Wakeford, 1960.

Figure 5.1-1
BASIC CONFIGURATION OF THE
NIKE AJAX MISSILE

Prepared for:
U.S. Army Toxic and Hazardous
Materials Agency
Aberdeen Proving Ground, Maryland



KEY

MTR	MISSILE-TRACKING RADAR
TTR	TARGET-TRACKING RADAR
ACQR	ACQUISITION RADAR

SOURCE: U. S. Army, 1956.

Figure 5.1-2
ACKING-INTERCEPT PROCESS OF THE NIKE AJAX MISSILE

Prepared for:
U.S. Army Toxic and Hazardous Materials Agency
Aberdeen Proving Ground, Maryland

related control equipment) was mobile, capable of being packaged into lightweight, van-type trailers (Ordway and Wakeford, 1960; Burgess, 1957).

5.1.2 PROPELLANTS

The Ajax first stage was powered by the XM-5 booster, which burned a cast, double-based solid propellant. The propellant grain and igniter were contained in a steel casing, which fell to the ground intact after burnout. Under normal conditions, the booster had a total burn time of 3.4 seconds, at the end of which it was jettisoned and the missile entered the second stage.

The Ajax second stage burned jet fuel (JP-4), with IRFNA used as an oxidizer. Aniline/furfuryl alcohol, later replaced by unsymmetrical dimethyl hydrazine (UDMH), were used as a starter fluid. In normal flight, the sustainer motor burned for 70 seconds and consumed 135 kilograms (kg) of JP-4 (Burgess, 1957; Cagle, 1973).

5.1.3 WARHEADS

Nike Ajax was armed with three high-explosive warheads. As shown in Fig. 5.1-3, these were mounted to the nose, center, and aft of the missile. The warheads were activated by two arming mechanisms and five detonating cords, following burst orders issued by the computer in the battery control trailer (U.S. Army, 1956).

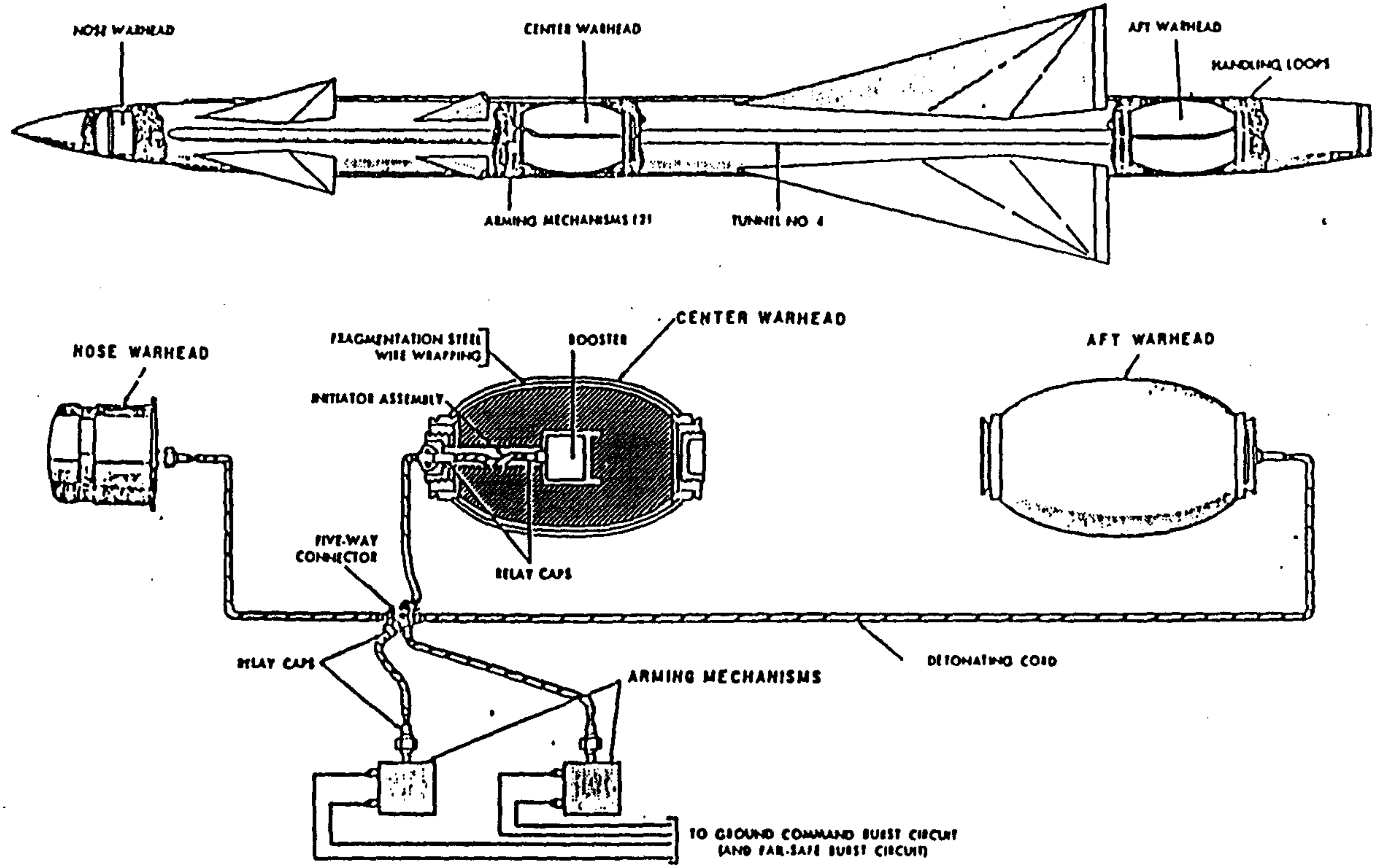
5.1.4 SUPPORT EQUIPMENT

The equipment utilized in each of these areas is itemized below, as described in Procedures and Drills for the Nike I System (U.S. Army, 1956).

<u>Battery Control Area</u>

1. <u>ACQR</u>: This radar, composed of the acquisition antenna, receiver, and transmitter, was used to detect, observe, identify, and designate selected targets. Operator controls and displays were located in the battery control trailer.

9 1 1 2 5 1 7 9 4



SOURCE: U. S. Army, 1956.

Figure 5.1-3
NIKE AJAX WARHEAD
POSITIONS AND CONSTRUCTION

Prepared for:
U.S. Army Toxic and Hazardous Materials Agency
Aberdeen Proving Ground, Maryland

2. TTR: This radar was composed of the tracking antenna, receiver, and transmitter, mounted on a drop-bed antenna trailer. The three operator's controls and displays (azimuth, elevation, and range) were located on the target console in the radar control trailer. The TTR tracked the designated target and furnished target present position data to the computer.
3. MTR: This radar was composed of the missile-tracking antenna, receiver, and transmitter, mounted on a drop-bed antenna trailer. The operator's controls and displays were located on the missile console in the radar control trailer. The MTR tracked the missile, supplied the computer with missile present position data, and provided a communication link for transmitting orders from the computer to the missile. The MTR was similar in appearance to the TTR.
4. Battery Control Trailer: The battery control trailer contained the acquisition radar cabinet assembly, the battery control console assembly, the computer assembly, an early warning plotting board, and an event recorder and switchboard cabinet assembly. The battery control console assembly contained the displays and controls required by the acquisition radar operator, the battery control officer, and the computer operator.
5. Radar Control Trailer: The radar control trailer contained the target console assembly, the missile console assembly, the radar power cabinet assembly, and the radar range and receiver cabinet assembly. The missile and target consoles contained the controls and displays required for the MTR and TTR operators.
6. Radar Collimation Mast Assembly: This assembly was composed of the radar frequency test set, the radar collimation mast, and the target-head assembly. It was used in collimating, testing, and adjusting the MTR and TTR.
7. Electrical Generating Equipment: This equipment produced the necessary electrical power to operate the equipment in the fire control area. Commercial power with electrical converters to change 60-cycle power to 400-cycle power was utilized where available.

8. Battery Control Area Cable System: This cable system interconnects the various elements in the battery control area.
9. Interarea Cable System: The interarea cable system included the cables necessary to connect the battery control area with the launching area. When cable installation and easement costs for the interarea cable were excessive, wire and radio voice control were used.
10. Maintenance and Spares Trailer: This trailer provided facilities for storing portable test equipment, spare components, and spare parts. Components of the ACQR were carried in this trailer during march order.

Launching Area

1. Launching Control Trailer: The launching control trailer contained the launching control panel, the launching control switchboard, and the test responder. The launching control panel contained the controls, displays, and communications equipment necessary to supervise and monitor the activities of the launching sections during an engagement and to act as a relay station between the launching sections and the battery control area.
2. Launching Section Control Cabinet: This cabinet, located underground in the underground magazine storage-type sites or in the launching section revetment in aboveground installations, contained the necessary controls, indicators, and communication facilities to enable a launching section to control the preparation and firing of its rounds. It also coordinated the activities of the launching section with the launching control panel operator in the launching control trailer. It consisted of a launching section control panel and a launching section power cabinet.
3. Launcher-Loader Assemblies: The launcher-loaders provided the equipment necessary to accomplish the physical operations at the launching site for storing, loading, and firing the rounds.
4. Electrical Generating Equipment:
   a. Aboveground sites--electric power for aboveground sites was supplied by 400-cycle, 30-kilowatt (kW) engine generators, or by commercial sources with suitable converters when available.

b. Underground sites--electric power for underground sites is supplied by 150-kW, 60-cycle diesel generators or by commercial sources, when available. Direct 60-cycle power was used for the elevator. Where 400-cycle power was required, the 60-cycle power was converted to 400-cycle power by means of frequency converters.

5. Launching Area Cable System: This system interconnects the various elements of the launching area.

5.2 HERCULES

5.2.1 CONSTRUCTION

Preliminary design of Nike Hercules called for a 2-stage system, employing a cluster of four Ajax XM-5 propellant boosters rigged to burn as one motor and fitted into a single casing in conjunction with four Ajax liquid propellant (later changed to solid propellant) sustainer motors. The mission of the system was to attack, with one atomic warhead, aircraft formations traveling at speeds up to 1,600 kph and at altitudes up to 18,288 m. The horizontal range of the missile from the launching site was to be approximately 45,700 m,

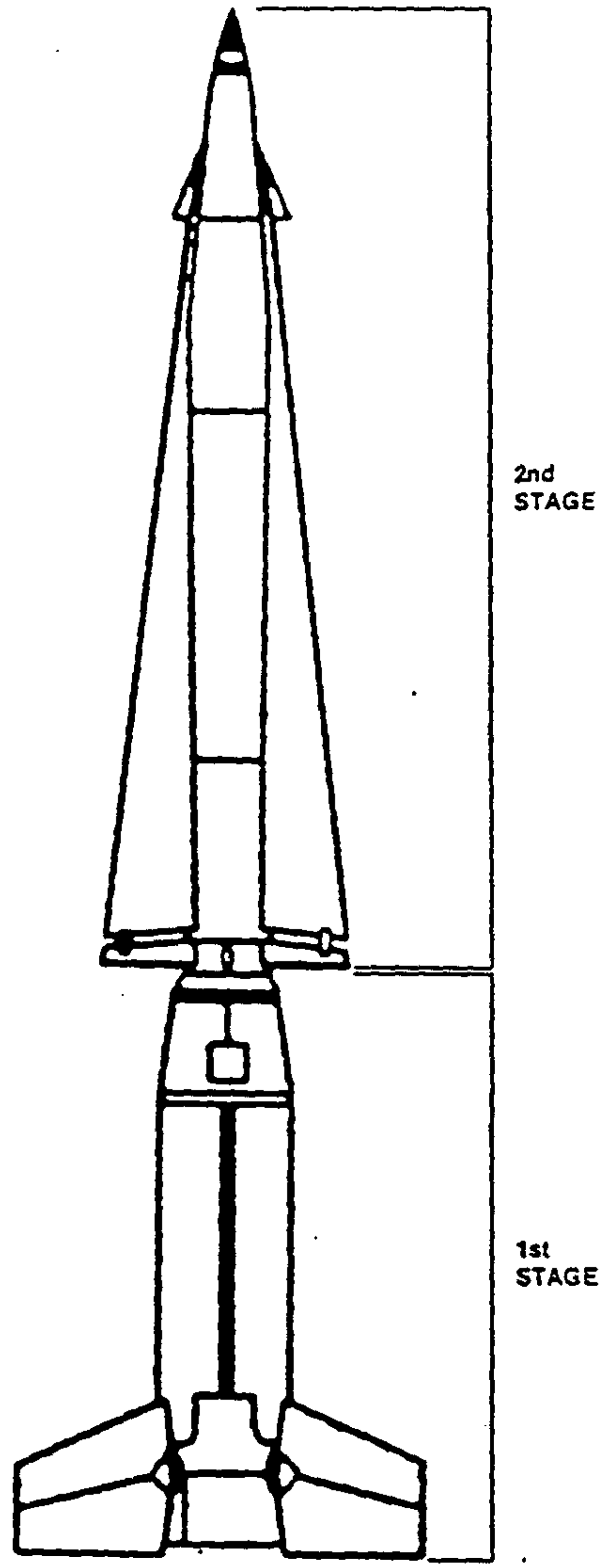
As finally developed, the Ajax and Hercules missiles could be launched from the same site. The Hercules was launched vertically and was propelled through the first stage of flight by the booster, which was jettisoned following propellant burn out. The sustainer motor then was ignited and carried the missile to its maximum height. Stabilization and steerage were accomplished by four fixed fins with trailing-edge control surfaces mounted to the aft of the missile. The Hercules guidance system was similar to that of the Ajax missile, was composed of an ACQR for locating all targets within range, a TTR to provide continuous surveillance of the target once identified, and an MTR (command guidance) radar to lock onto the missile itself and guide it to the intercept point.

In outward appearance, the Hercules was similar to the Ajax (see Fig. 5.2-1). As demonstrated by the construction and performance data listed in Table 5.2-1, however, Hercules was in every way a larger, more powerful weapon than the Ajax.

Table 5.2-1. General Construction and Performance Data for the Nike Hercules

Characteristic	Specification
Length (m)	8.2 (11.9 with booster)
Diameter (cm)	80
Weight (kg)	
Loaded	2,270 (4,721.6 with booster)
Payload	454
Range (km)	120 - 128
Altitude (km)	56
Velocity (kph)	3,528
Sustainer Thrust (kg)	4,540
Sustainer Propellant	Solid
Booster Propellant	Solid
Booster Firing Time (seconds)	4

Source: Modified from Ordway and Wakeford, 1960.



SOURCE: Ordway and Wakeford, 1960.

Figure 5.2-1
BASIC CONFIGURATION OF THE
NIKE HERCULES

Prepared for:
U.S. Army Toxic and Hazardous
Materials Agency
Aberdeen Proving Ground

5.2.2 PROPELLANTS

As mentioned in Sec. 5.2.1, the first stage of the Hercules missile was powered by the solid-propellant XM-5 cluster, which became standardized for the Hercules system. The second-stage sustainer motor was modified throughout the system development. Initial test models used a liquid sustainer motor fueled by a mixture of 40-percent UDMH and 60-percent JP-4, which was known as JPX. Between 1955 and 1956, the sustainer cluster was redesigned using motors fueled by JP-4, with IRFNA as an oxidizer.

The liquid sustainer motors continually malfunctioned during Hercules testing; therefore, a solid-propellant sustainer motor of the XM-30 series was developed and accepted in 1958 as a replacement for the liquid propulsion system. This model was fueled by an ammonium perchlorate-type propellant. Conversion to the solid propellant required general missile redesign, including rearrangement of the warhead and guidance systems within the missile casing (Cagle, 1973; Ordway and Wakeford, 1960). All Hercules missiles deployed at Nike batteries used the solid fuel engines.

5.2.3 WARHEADS

The primary warhead arming the Hercules missile was nuclear. Large nuclear payloads were designed for use against aircraft formations, while smaller payloads were employed against single aircraft. Other types of warheads, including high-explosive and fragmentation, were developed for use against low-altitude targets (Cagle, 1973).

5.2.4 SUPPORT EQUIPMENT

The basic Hercules battery, which utilized existing Ajax equipment to the fullest extent possible, involved three basic operations carried out in the launch area: assembly and testing, fueling and warheading, and launching. Equipment associated with each of these activities is listed in Table 5.2-2. In addition, this table designates which pieces of equipment were unique to Hercules, which items were developed to permit co-use by Ajax and Hercules, which were modified Ajax pieces, and which were unmodified Ajax items.

The design of the Hercules launching and handling equipment was essentially the same as that of the Ajax equipment. It remained virtually unchanged

Table 5.2-2. Support Equipment Characteristic of the Nike Hercules Battery

Equipment	No. Required For Hercules	New For Hercules Only	New For Ajax/Hercules	Modified Ajax	Existing Ajax
<u>Assembly and Testing</u>					
1. Capping Compressor	1				X
2. Propulsion Plumbing System Test Assembly	1			X	
3. Missile Dolly	3	X			
4. Warhead Section Adapter	3	X			
5. Main Body Hoist Beam	1	X			
6. Auxiliary Power Unit Fueling Equipment	1	X			
7. Missile Handling Rings	5 sets	X			
8. Hydraulic Test Stand	1			X	
9. Test Assembly Missile Electrical Equip.	1			X	
10. Servicing Assembly Propellant Draining	1			X	
11. Miscellaneous Tools and Equipment	1			X	
<u>Fueling and Warheading</u>					
1. Fuel Fill Equipment	1		X		
2. Propellant Hoist Assembly	1		X		
3. Oxidizer Fill Equipment	1		X		
4. Warhead Section Dolly	2	X			
5. Missile Hoist Beam	1	X			
6. Warhead Section Hoist Beam	1	X			
7. Booster Cluster Hoist Beam	1	X			
8. Booster Cluster Dolly	2	X			
9. Jato Hoist Beam	1				X
<u>Launching</u>					
1. Launcher	3		X		
2. Loading Racks	17		X		
3. Loading Frame	1		X		
4. Launching Rail	6	X			
5. Portable Test Set	1	X			
6. Portable Test Equipment Dolly	1				X
7. Launching Section Operation Equipment	1			X	
8. Launching Control Trailer	1			X	
9. Missile Booster Transporter Trailer	2				X
10. Trailer Adapter	2	X			

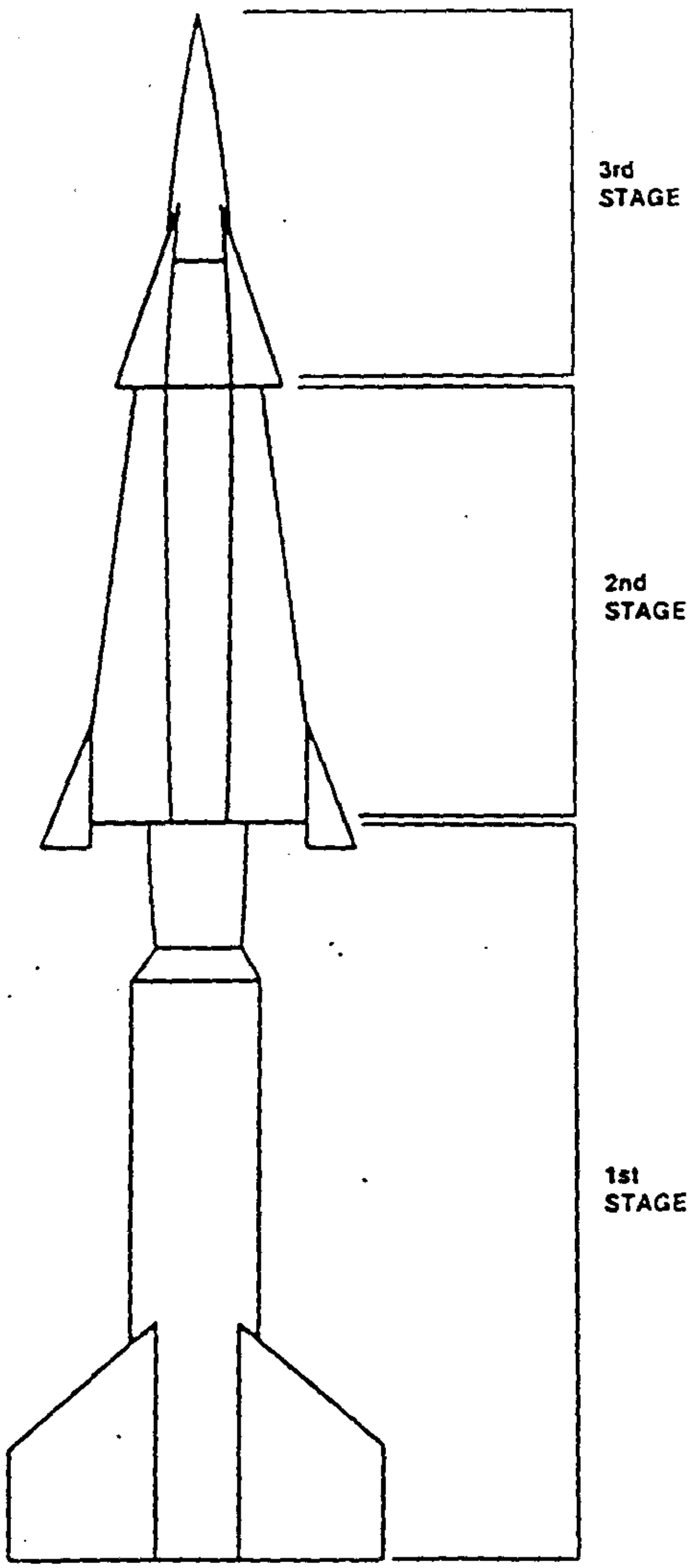
Source: Cagle, 1973.

throughout the life of the missile system. The basic guidance and control systems, however, were modified through the years to keep pace with advances in target aircraft technology (Cagle, 1973; Ordway and Wakeford, 1960).

5.3 ZEUS

Approximately 15.2 m in length, Nike Zeus was a 3-stage, solid-propellant missile capable of 204,300 kg of thrust in the first stage. It had a 480-km range and 320-km average altitude. Equipped with a nuclear warhead, it was the most powerful missile of its time (Ordway and Wakeford, 1960; Parson, 1962). The basic configuration of the Zeus is shown in Fig. 5.3-1.

The principles of guidance and propulsion used in the Zeus were the same as those for Ajax and Hercules (see Fig. 5.1-2). The warhead support system differed, however, in that it reportedly detected the entry of an ICBM target into the atmosphere by means of electro-magnetic disturbances created by the target (Parson, 1962).



SOURCE: Ordway and Wakeford, 1960.

Figure 5.3-1 BASIC CONFIGURATION OF THE NIKE ZEUS MISSILE	Prepared for: U.S. Army Toxic and Hazardous Materials Agency Aberdeen Proving Ground, Maryland

6.0 LIFE CYCLE OF TYPICAL NIKE BATTERY

The following sections describe the typical operations and activities associated with the construction, deployment, operation, maintenance, and conversion/deactivation of a Nike battery (Ajax and Hercules). The focus is on those operations and activities having the potential to generate toxic and hazardous materials.

6.1 AJAX

6.1.1 DEPLOYMENT

All Ajax systems were deployed on sites not previously established for missile deployment and on land for the most part acquired from civilian landowners. As a result, site preparation and construction was a much more significant activity than with subsequent deployment of Hercules systems, most of which were deployed at existing Ajax battery locations.

Limited specific information regarding site preparation was found, as the majority of battery personnel arrived after much of the initial site construction was completed. Initial site preparation involved cutting and filling to provide smooth terrain for subsequent construction and excavation for magazines. Rugged terrain necessitated removal of material from the site. The disposition of this material and subsequently excavated material is not known, although it likely depended upon local need for fill or the presence of a suitable local dumping area.

The preparation of earthen pads for the subsequent construction of buildings, concrete pads, and vehicle areas was also necessary. Some site drainage alterations were probably required.

Establishment of utilities service was also part of site preparation. This included laying pipe for water and/or sewer services, well construction, and laying pipelines for fuel oil or natural gas supply, all dependent upon the provisions for utility service to the site. Also, at least at some sites, landfills were established for waste disposal.

Major construction at the three main battery areas included:

o Launch area --	Magazine and elevators
	Launch pads
	Material storage buildings
	Assembly building(s)
	Repair building(s)
	Latrine(s)
o Battery Control Area --	Launch control building(s)
	Generator pads
	Radar and tower pads
	Latrine(s)
	Material storage area
o Barracks --	Barracks
	Mess hall
	Latrines
	Recreation/support services

Ancillary construction activities included some or all of the following:

- o Placement of non-missile fuel tanks;
- o Construction and placement of auxiliary generator pads;
- o Construction of fences and gates;
- o Placement of utility poles, lines, switching yards;
- o Placement of water and sewer lines; and
- o Placement of natural gas or fuel oil lines.

Utility construction depended primarily on how service was provided to the site. Nike batteries generally used existing commercial sources, and therefore, only onsite connections and distribution systems were necessary. Where sewerage was handled onsite, no connections were necessary.

Missile assembly primarily involved the unification of missile components shipped inert to the site in special containers. Components were removed from the containers and assembled, generally in a designated assembly area or building.

Additionally, assembly operations involved attaching and aligning the fins and mounting the missile to the launch carriage or assembly. Warhead placement, also a part of the initial assembly, was performed in a designated "warheading" building. Additional aspects of assembly involved pressurization, addition of hydraulic fluids, and connection of electrical/electronic cable systems for integration with Launch Control.

Assembly operations presented minimal potential for contaminant generation, although there was some use of solvents for cleaning of electrical contacts and assembly points. There was also some spillage of hydraulic fluids during the initial filling process.

Testing of missiles and support equipment at battery sites was limited to integrity/function testing of electrical, electronic, hydraulic, and mechanical systems. In addition, testing of personnel response and mobilization was conducted. All firing was restricted to designated proving ground ranges.

In the permafrost regions of Alaska and Greenland, aboveground facilities and the installation of refrigerant systems to cool any surfaces contacting the ground were required.

6.1.2 OPERATION

During the operational life of an Ajax battery, several onsite operations involved toxic and hazardous materials. These operations included fueling, defueling, and the addition/changeout of missile constituents; support equipment maintenance and repair; and materiel handling and storage. Approved general operational procedures appear to have been consistent throughout CONUS, although many battery-specific variations were found.

Contaminants of concern for the Ajax missile include liquid fuel, UDMH, aniline, and IRFNA. In general, these materials were handled so as to generate minimal spillage or ground contamination, primarily due to concerns for the safety of battery personnel. Typically, these materials were pumped or gravity fed into the missile from containers and returned to containers for turn-in during maintenance or disassembly. Some spillage occurred from

line disconnecting and flushing, but in most instances this was limited. Spillage was typically washed into a ground sump at the fueling/defueling point.

Some batteries reportedly made routine use of a sump for disposal of IRFNA. Magazine areas infrequently received spillage of fuels and hydraulic fluids from component leakage or rupture. In such cases, the majority of the spillage was handled by absorbent rags or compounds which were subsequently disposed of offsite with domestic trash. The area was then washed down. Wash water went to the magazine sump and was subsequently pumped to the surface, and discharged to the surface drainage system.

With the Ajax system, a 2-year rotational maintenance protocol was established about 1960. Prior to this, there was no routine maintenance of the missile or launcher, but only "as-needed" maintenance and repair. Rotational maintenance involved removal and replacement of fuel, UDMH, and IRFNA. In addition to the 2-year rotational maintenance, electrical batteries were changed-out monthly (one battery per missile). Battery acid was disposed of in a variety of ways, including dumping into a ground sump, dumping into a soda pit, pouring into a soda drum, or pouring into the latrines.

Disposal of hydraulic fluid from missiles varied, dependent again on the individual battery. Sometimes the fluid was flushed into drums for turn-in, flushed into a ground sump, or used for weed control around buildings and fences. Most of the hydraulic fluid used was contained in missile launchers. This fluid was changed annually or more frequently, in some cases. Quantities of hydraulic fluid dumped reportedly ranged from 1,900 to 3,785 l per year. In addition, hydraulic fluid spills in the magazines and at launch pads were common, both from routine maintenance and rupture of lines.

Support equipment maintained onsite included launchers, vehicles, and electrical generators. The typical Ajax battery had a 10- to 12-vehicle

motor pool split between the battery control and launch areas and one or sometimes two generator buildings. Only organizational maintenance (oil changes, tune-ups, and minor repair) was conducted at the battery site. Primary wastes generated from support equipment maintenance were battery acid, waste oil, brake fluid, transmission fluid, and spent solvents.

Vehicle, generator, and launcher maintenance/repair conducted in the launch area generally involved the use of various solvents, cleaners, paints, and thinners. Notable were trichloroethane, trichloroethylene, toluene, carbon tetrachloride, acetone, and alcohol. These were used for a variety of functions, including cleaning of contacting parts, cleaning of grease spills or stains, and overall cleaning in preparation for painting.

Typically, the use of solvents and cleaners was concentrated in the launch area and repair areas. Quantities used at any one time were generally low, with little waste generated. However, at certain batteries and prior to inspection, much larger quantities were used for general surficial cleaning. Typical quantities used reportedly ranged from 30 to 120 l per month for trichloroethylene and 190 to 380 l per month for other solvents, primarily non-chlorinated hydrocarbons such as Stoddard solvents or PD-680.

Waste solvents and cleaners were typically poured into a ground sump where they soaked into the ground, but were sometimes drummed for turn-in. When larger quantities were used for overall cleaning, residues were washed into a sump or onto the ground surface. Battery acid was dumped into a sump or otherwise disposed of onsite. Waste oil was frequently dumped into a sump, although drumming for turn-in was also commonly practiced.

Maintenance/repair activities at the battery control area centered on electrical and electronic equipment and components. Primary substances used in maintenance were the same solvents and cleaners used in support equipment maintenance. These were used in small quantities to clean electronic components and contacts; the process was often followed by blow-drying. Wastes were thus minimal and would have been dumped on the ground or into a sump.

motor pool split between the battery control and launch areas and one or sometimes two generator buildings. Only organizational maintenance (oil changes, tune-ups, and minor repair) was conducted at the battery site. Primary wastes generated from support equipment maintenance were battery acid, waste oil, brake fluid, transmission fluid, and spent solvents.

Vehicle, generator, and launcher maintenance/repair conducted in the launch area generally involved the use of various solvents, cleaners, paints, and thinners. Notable were trichloroethane, trichloroethylene, toluene, carbon tetrachloride, acetone, and alcohol. These were used for a variety of functions, including cleaning of contacting parts, cleaning of grease spills or stains, and overall cleaning in preparation for painting.

Typically, the use of solvents and cleaners was concentrated in the launch area and repair areas. Quantities used at any one time were generally low, with little waste generated. However, at certain batteries and prior to inspection, much larger quantities were used for general surficial cleaning. Typical quantities used reportedly ranged from 30 to 120 l per month for trichloroethylene and 190 to 380 l per month for other solvents, primarily non-chlorinated hydrocarbons such as Stoddard solvents or PD-680.

Waste solvents and cleaners were typically poured into a ground sump where they soaked into the ground, but were sometimes drummed for turn-in. When larger quantities were used for overall cleaning, residues were washed into a sump or onto the ground surface. Battery acid was dumped into a sump or otherwise disposed of onsite. Waste oil was frequently dumped into a sump, although drumming for turn-in was also commonly practiced.

Maintenance/repair activities at the battery control area centered on electrical and electronic equipment and components. Primary substances used in maintenance were the same solvents and cleaners used in support equipment aintenance. These were used in small quantities to clean electronic components and contacts; the process was often followed by blow-drying. Wastes were thus minimal and would have been dumped on the ground or into a sump.

Equipment replacement in the battery control area included small capacitors and transformers and low-level radiation sources such as dials and electron tubes. These were typically turned in to property disposal channels. When tube breakage did occur, it was handled by bagging and turn-in for disposal.

Maintenance/repairs in the barracks area were generally limited to typical cleaning, painting, carpentry, plumbing, and electrical activities. The only wastes of concern generated would be paint, paint thinners, and possibly cleaning agents (caustics, soaps). Paint waste and waste thinners were likely ground dumped or poured into latrines, as would also likely be the case with the cleaning agents.

It is not known if mess halls were equipped with grease traps and, if so, how these were emptied and how the grease was disposed of. Other garbage would likely have been hauled offsite with other domestic trash.

All chemicals and fuels used for missile operation, as well as solvents, paints, and cleaners used in the maintenance of equipment, were stored in designated buildings or on concrete sand-bag bermed pads with or without roofs. Solvents and cleaning agents were routinely kept on hand in 55-gallon (gal) drums. Materials were segregated based on compatibility, resulting in a number of storage buildings or areas. Buildings generally had bermed floors to contain leakage or spillage. In some cases, absorbent materials were placed on the floor to absorb leaked or spilled material. Otherwise, leakage or spillage would be handled by absorption and decontamination (i.e., flushing, neutralizing).

Quantities of missile fueling liquids stored were limited to those needed to service two or three missiles. Fuels for vehicles were stored in aboveground and underground tanks. No leak checking was conducted, and spillage during fuel transfers was reportedly frequent.

Waste materials (solvents, fuels, UDMH, IRFNA) were drummed and stored in a bermed building or storage area for pick-up by property disposal personnel.

The quantities of waste materials in storage at any one time were generally small. Information indicates that leakage or spillage in the storage areas was uncommon and involved very small quantities. Overall, potential for ground contamination from storage areas appears to be small.

6.1.3 CONVERSION/DEACTIVATION

Beginning in the late 1950s, deactivation and/or conversion of batteries from Ajax to the Hercules system were initiated under the direction of the missile battalions. A number of batteries remained as Ajax or were only partially converted to Hercules. In general, deactivation was a reversal of the deployment process in terms of material handling and disposition. Ajax hardware was shipped to depot-level supply points, while expendable items that could be used with Hercules were retained at converted sites. At deactivated sites, both equipment and supplies were returned to depot-supply.

The deactivation and disposition of the missile and launcher were generally a reversal of the initial assembly/activation process. The missile and launcher were purged of fuel, UDMH or aniline, IRFNA, and hydraulic fluid using normal defueling procedures. Wastes were either recontained for property turn-in or disposed of in onsite ground sumps or onsite spectic systems. Missiles were disassembled and recontainerized.

It was also frequently necessary during a conversion or deactivation process to dispose of fuels and other chemicals in excess of recorded inventory. This material was generally dumped onsite in a ground sump or on the surface. Some instances were reported where excess material was transported offsite and dumped in open areas nearby, and limited instances of full UDMH containers being found buried at old Nike sites have been documented. All fresh fuels and other chemicals were typically turned in to depot supply. All magazine hardware was retained for subsequent disposition or conversion. Elevators remained functional.

Some equipment alterations were required for the conversion from the Ajax to the Hercules system. Some magazines needed to be enlarged (width) to contain the larger Hercules missiles. The launcher and missile systems were larger and heavier, requiring a higher-capacity lift system. The launcher and rail systems were also replaced. Any alteration or replacement of existing structures would represent limited potential for contaminant generation, although some POL products and hydraulic fluids would have been wasted during replacement or alteration and probably disposed of onsite.

After battery personnel departed the battery site, physical closure or subsequent maintenance was the responsibility of the U.S. Army Corps of Engineers (COE).

Prior to reporting any property eligible for excess, COE personnel generally conducted an inspection and survey of the property, and secured the property until subsequent disposition. Typically, the inspection or survey would consider aspects of safety and contamination, as well as securing the site from public access.

6.2 <u>HERCULES</u>

For the most part, the life cycle features of a typical Hercules battery varied little from those of the Ajax system. In most cases, Hercules missiles were deployed at existing Ajax battery locations. Other features of deployment and deactivation/site closure were essentially similar to those for Ajax, although there were some operational differences. The following discussion will detail only those aspects of the Hercules life cycle different from the Ajax life cycle. It must be noted that, at some batteries, both Hercules and Ajax were deployed at a site for at least some period of time.

6.2.1 DEPLOYMENT

Site preparation was necessary only at those sites where the deployment was new, rather than at a conversion site. New site preparation was essentially similar to that detailed for Ajax.

New construction at converted sites included alteration of storage facilities; some expansion of missile assembly, warheading, and repair buildings; and changes in the rail transport and missile lift assemblies.

Assembly and testing of Hercules were similar to Ajax; the only exception was the use of solid fuel in Hercules, thus eliminating the liquid fueling procedures. The solid fuel was a cast propellant, with the grain being an integral part of the motor, eliminating the need for fuel handling.

6.2.2 OPERATION

The major operational changes involved the solid fuel system adopted for the Hercules. This eliminated the UDMH, aniline, IRFNA, and JP-4 from the operations and greatly reduced routine maintenance requirements. This also reduced the variety and quantity of fresh and waste liquids handled at the site. Support equipment maintenance/repair operations for Hercules were similar to those of the Ajax system and involved the use of solvents and cleaning agents. The use of carbon tetrachloride and trichloroethylene was gradually phased out during Hercules, and PD-680 or Stoddard II solvents were introduced. Reportedly, the extent of solvent use depended somewhat on particular tasks performed at the battery, which, in turn, depended on the expertise of personnel assigned to the site.

Early models of the Hercules used ethylene oxide to power control surfaces. This material was generally drained into containers for turn-in or into a ground sump. Early Hercules also used three liquid electrolyte batteries per missile. These were changed-out monthly, the waste acid sent to ground sumps, latrines, or to neutralizing drums for turn-in. The liquid-electrolyte batteries were later replaced by nickel-cadmium batteries, which did not involve any fluid changing. These were replaced monthly; the old batteries were turned in to property disposal personnel for disposition.

There appear to be no significant regional differences in the operational aspects of the Hercules system. Variability was primarily due to battery-to-battery differences, as was the case with the Ajax system.

Storage of materials at the typical Hercules battery was similar to storage at Ajax batteries. There was some indication that onsite storage of waste POL, solvents, and paints may have increased in the years after 1965 due to increased awareness of potential problems related to onsite dumping.

6.2.3 CONVERSION/DEACTIVATION

The Hercules was the final system deployed under the Nike program. As a result, the final phase of the Hercules life cycle was one of deactivation and site closure. Essentially, the deactivation/closure process was identical to that of Ajax sites not converted to Hercules and largely consisted of equipment inactivation and turn-in. Missiles were disassembled and containerized for shipment. All launcher and magazine hardware was removed, generally excluding the elevator systems. Containerized wastes and fresh materials were turned into depot supply. Excess inventories were typically disposed of onsite, generally into a ground sump. All launch control, radar, and support equipment was turned in for disposition.

Site closure was primarily the responsibility of the appropriate COE district and may or may not have involved a closure survey of contamination and safety aspects. The battery sites were at least physically secured from unauthorized entry. Final closure was largely dependent upon subsequent usage (leasing, excessing, etc.). App. F provides a listing of sites and their property disposition after closure. No record was found of any routine site decontamination or of any formal procedure for well capping or magazine closure. Some site cleanups have been conducted on a case-by-case basis in response to specific problems or complaints.

7.0 ENVIRONMENTAL RELEASES

The materials potentially released to the environment at Nike sites, their quantities, and their sources are summarized in Table 7.0-1. Materials, use areas, and disposal methods were confirmed by at least two independent sources. Quantities used and dates reflect the best possible estimate based on reports which were in some cases widely variable. Some quantity estimates (e.g., diesel and gasoline consumption) were derived from related information, such as the number of personnel, vehicles, and generators associated with a battery. The quantities listed in Table 7.0-1 are the annual usage rates and represent the maximum potential release to the environment and not the quantities actually disposed of onsite. The behavior and persistence of those materials listed in Table 7.0-1 are discussed in this section.

7.1 CHLORINATED ORGANIC SOLVENTS

Between the early 1950s and the mid-1970s, a variety of chlorinated organic solvents were utilized on Nike sites for cleaning and maintenance activities. At many of the early Ajax sites carbon tetrachloride was used as a multi-purpose solvent. Carbon tetrachloride was gradually replaced, in turn, by trichloroethylene and trichloroethane.

As shown by the data in Table 7.1-1, carbon tetrachloride, trichloroethylene, and trichloroethane are nonreactive compounds in the environment. The solvents are not subject to photolytic, oxidative, hydrolytic, or biologic reactions to a significant degree.

The volatility of the compounds is such that a portion of the solvent would have evaporated during use, reducing the amount that might have been disposed of on the site itself. The volatility of these solvents also precludes any residual contamination of surface waters, except where contaminated ground water might be contributing to surface water flows.

Table 7.0-1. Summary of Environmental Releases at a Nike Missile Battery

Contaminant	Quantity Used (l/year)	Area of Use*	Routine Disposal Methods: Primary	Routine Disposal Methods: Secondary	Incidental Releases	Dates
Carbon Tetrachloride	1,000- 2,000	LA, Motor Pool	Sump	Surface Dump	--	1954-1962
Trichloroethylene	360- 1,400	LA, Motor Pool	Sump	Surface Dump	--	1956-1970
Trichloroethane	1,000- 2,000	LA, Motor Pool	Sump	Surface Dump	--	1958-1974
IRFNA**	500- 1,500	Fuel/Defuel	Sump	Turn-in	Line Rupture	1954-1964
Aniline-Furfuryl Alcohol**	20- 30	Fuel/Defuel	Turn-in	Dump/Burial	Line Rupture	1954-1958
UDMH**	20- 30	Fuel/Defuel	Turn-in	Dump/Burial	Line Rupture	1956-1964
Battery Electrolyte	100- 300	LA, Motor Pool	Sump	Sewer	--	1954-1978
JP-4**	2,000- 3,000	Fuel/Defuel	Turn-in	--	Leakage	1954-1978
Diesel/Gasoline	50,000-100,000	Motor Pool, Generator	Consumptive Use		Leakage	1954-1978
Stoddard Type II	2,000- 4,000	LA, Motor Pool	Sump	Turn-in	--	1965-1978
No. 2 Fuel Oil	20,000- 50,000	LA, BCA, Housing	Consumptive Use		Leakage	1954-1978
Motor Oil	400- 600	Motor Pool	Turn-in	Sump	--	1954-1978
Hydraulic Fluid	1,900- 3,780	LA, Motor Pool	Sump	--	Line Rupture	1954-1978

* LA = Launch Area
BCA = Battery Control Area
** Ajax Only

Source: ESE, 1983.

Table 7.1-1. Physical and Transport Data for Chlorinated Organic Solvents

Property	Carbon Tetrachloride	Trichloroethylene	1,1,1-Trichloroethane	1,1,2-Trichloroethane
Molecular weight	153.82	131.39	133.41	133.41
Melting point, (°C)	-22.99	-73	-30.41	-36.5
Boiling point, (°C)	76.54	87	74.1	113.77
Ionization constant	NA*	NA	NA	NA
Water solubility (mg/l)	785 (20 °C)	1100 (20 °C)	720 (25 °C)	4500 (20 °C)
Octanol-water partition constant (K_{ow})	912	69	320	117
Sediment-water partition constant (K_{oc})	439	33	152	56
Henry's constant (atm m^3 mol^{-1})	0.023	0.0091	0.03	7.42×10^{-4}
Vapor pressure (torr)	90 (20 °C)	57.9 (20 °C)	123 (25 °C)	19 (20 °C)
Photolysis rate constant (hr^{-1})	NA	NA	NA	NA
Oxidation rate constant ($mole^{-1}$ hr^{-1})	<<360	$<10^3$	<<360	<<360
Hydrolysis rate constant (hr^{-1})	NA	0	1.7×10^{-4} (neutral, 25 °C)	1.2×10^{-7}
Biotransformation rate constant (ml $cell^{-1}hr^{-1}$)	1×10^{-10}	1×10^{-10}	NA	3×10^{-12}

Source: Mabey *et al.*, 1981.

*NA - Not Appreciable. While actual values were not provided in the source literature, these rates and constants are either 0 or so low that the associated transformation processes are inconsequential in the environment.

The sediment-water partition constants (K_{oc}, Table 7.1-1) indicate that solvents poured onto the ground would experience some retardation relative to percolating water due to adsorption by soil organic matter. Since the extent of sorption is related to the organic carbon content of soils by the K_{oc}, the degree of sorption will vary from one soil to another, with sandy soils sorbing less than more organic soils. Temporary immobilization in the upper layers of the soil provides further opportunity for volatilization prior to incorporation into ground water.

The lack of hydrolytic reactivity and the tendency to be sorbed suggest that once introduced into ground water, the chlorinated solvents could be persistent, particularly in those instances where ground water movement is slow.

Presented in Table 7.1-2 is a summary of U.S. Environmental Protection Agency (EPA) criteria for chlorinated solvents and other parameters associated with Nike wastes. These criteria are recommended for the protection of human health and for maintenance of a healthy, freshwater aquatic ecosystem. National Interim Primary Drinking Water Regulation (NIPDWR) standards are included when applicable. The aquatic life criteria listed reflect levels of acute toxicity to typical, but not necessarily the most sensitive, aquatic organisms. The human health criteria cited are levels at which an incremental increase of 10^{-5} in cancer risk may result over a lifetime due to consumption of contaminated water or organisms inhabiting the water. The criteria in Table 7.1-2 do not apply to ground water, except where they serve as a drinking water supply. Ground water does, however, become subject to surface water criteria when it surfaces as seeps, springs, or otherwise becomes incorporated in surface water.

7.2 HYDROCARBONS

A variety of hydrocarbon products were utilized or stored on Nike batteries, including JP-4, diesel fuel, gasoline, fuel oil, hydraulic fluid, and motor oil. Each of these products consists of a large number of components

ɔle 7.1-2. Current EPA Water Quality Standards/Criteria for Selected Contaminants

rameter	Maximum Drinking Water Contaminant Level (ug/l)	Freshwater Aquatic Life*		Human Health*	
		24-Hour Average (ug/l)	Maximum Level (ug/l)	Ingesting Water & Organisms (ug/l)	Ingesting Organisms Only (ug/l)
ad	50	20.0	400	50	--
1,1-Trichloroethane	--	--	31,200	18,400	1×10^6
1,2-Trichloroethane	--	--	--	6	418
ichloroethylene	--	--	45,000	27	807
rbon Tetrachloride	--	--	35,200	4.0	69.4
trate (as N)	10 mg/l	--	--	--	--

:riteria for 10^{-5} incremental increase of cancer risk (one additonal case of cancer in populations ɔf 100,000).

ɔurce: EPA 1980, 1981

(individual compounds and isomers), discussed in aggregate due to their similar properties.

Once released either on or under ground, petroleum products, attenuated somewhat by sorption on soil, move downward until either a restrictive horizon or the water table is intercepted. The portion that reaches the ground water is partitioned into (1) a free product that forms on top of the water and spreads laterally, and (2) a dissolved or emulsified product in the aquifer (Yaniga, 1982). The amount of hydrocarbon dissolving in the water is small and depends in large part on the type of petroleum product. Typical saturation concentrations are 0.1 to 5 milligrams per liter (mg/l) for kerosene and petroleum, 10 to 50 mg/l for diesel oil and extra light heating oil, and 50 to 500 mg/l for gasoline (Matthess, 1982). The products tend to be persistent, particularly in ground water where photolysis and evaporation are not major processes.

Petroleum products in ground water are objectionable primarily because of odor and taste (organoleptic) problems. The odor and taste thresholds of petroleum products vary from about 0.001 mg/l (gasoline, diesel fuel, heating oil) to about 10 mg/l (benzole) (Matthess, 1982) and are less than toxic concentrations. At toxic levels, the contaminated water is unpalatable. Consequently, EPA has not established quantitative water quality criteria for petroleum hydrocarbons for the protection of human heath, since organoleptic constraints would preclude the ingestion of water contaminated to toxic levels. Other problems may also be associated with petroleum-contaminated water, including fire and explosive hazards.

7.3 IRFNA

IRFNA consists of nitrogen dioxide dissolved in nitric acid. IRFNA is a powerful oxidizing agent and a strong acid and is, therefore, very reactive in the environment. Virtually all reactions, including neutralization of spilled or excess IRFNA, result in nitrate anions.

Water containing large quantities (greater than 100 mg/l) of nitrate is bitter tasting and may cause physiological stress. The NIPDWR standard for nitrate in drinking water is 10 mg/l.

7.4 UDMH Unsymmetrical dimethyl hydrazine

UDMH, used in small quantities as a starter fluid in later Ajax missiles, is a powerful reducing agent with a melting point of -58 degrees Celsius (°C) and a boiling point of 63.9°C. UDMH in the environment undergoes both hydrolysis and oxidation.

In a series of soil stability studies (ESE, 1982) it was found that less than 10 percent of the UDMH spiked onto a soil sample could be recovered after 1 hour. Recognizing that UDMH is volatile, a second experiment was run using capped containers to eliminate loss due to volatilization. Under these circumstances the half-life of UDMH on moist soil was found to be less than 1 hour. The study concluded that UDMH is not persistent in moist soil.

7.5 ANILINE--FURFURYL ALCOHOL

Aniline was burned with furfuryl alcohol as a starter fuel in the very early years of the Ajax program in the second-stage starter fluid, and the small quantities disposed of were poured on the ground.

Aniline has a melting point of -6°C, a boiling point of 184°C, and a water solubility of 3,700 mg/l. While environmental fate data were not located for aniline, data for benzidine (EPA, 1981), a similar compound, suggest that aniline is not a persistent compound. Both oxidation and photolysis contribute to its transformation. In addition, benzidine is strongly sorbed onto clays and is not significantly bioaccumulated.

Furfuryl alcohol is very soluble in water and has a low volatility (vapor pressure = one torr at 31°C). It behaves as a primary alcohol, undergoing

oxidation and acid hydrolysis. While moderately stable and moderately toxic (LD_{50} = 275 mg/kg in rats), the small quantity of furfuryl alcohol that was discarded and its high solubility suggest that it would not be present in the environment in significant concentrations.

7.6 BATTERY ELECTROLYTE

The disposal of lead battery electrolyte, often accompanied by acid neutralization, resulted in the release of lead to soils and potentially to surface water and ground water. Normally lead is immobilized in soil, its very low solubility restricting downward movement into ground water (Brady, 1974). The disposal of large quantities of unneutralized electrolyte at the same location each month would enhance the possibility of contaminating ground water.

7.7 RADIOACTIVE MATERIALS

The maintenance of Nike Hercules nuclear warheads required periodic wipe tests to establish the absence of radioactive leaks. The wipes were disposed of in facilities licensed by the U.S. Atomic Energy Commission (AEC). Often these facilities consisted of a lead-lined drum kept in a secure location. Defective electron tubes containing radioactive isotopes were also kept in these drums. The storage facilities were monitored for radioactivity in compliance with the terms of the AEC license. At the time of deactivation the storage facilities were reportedly closed and removed in accordance with AEC requirements. No instances of release of radioactive materials into the environment were reported.

7.8 RESIDUAL CONTAMINATION

Considering the quantities of waste materials released at Nike sites and the environmental properties of these materials, the potential for contaminants to still be present in the environment in significant concentrations is limited to only a few substances. At both Ajax and Hercules sites the use and disposal of chlorinated organic solvents, various hydrocarbon products, and battery electrolyte introduced persistent contaminants into the environment. In addition, nitric acid was disposed of on Nike Ajax

sites. The potential for such contaminants to have persisted to this time in undesirable concentrations varies greatly from site to site. The actual quantities released, method of disposal used, properties of soils, nature of the ground water system, utilization of ground water and soil systems, and general environmental conditions combine to mitigate or exacerbate any materials released at any given site.

Whether or not the contaminants were containerized at the time of disposal is particularly significant. Burial of materials in containers presents the possibility of environmental release at a later time when the container corrodes or breaks. In such cases the extent of existing contamination may be greater than what would have been expected, given the time that has elapsed since the Nike system was deactivated.

8.0 CONCLUSIONS

1. The Nike missile system in CONUS began with deployment of the Nike Ajax missile in 1954. Deployment of the Nike Hercules began in 1958, completely replacing the Nike Ajax by 1964. In 1974, the Nike Hercules was withdrawn from service as an anti-aircraft weapon in CONUS. Nike Zeus was developed and tested from 1956 to 1962, but was never deployed.

2. Nike missile sites were primarily located in the vicinity of major metropolitan areas and strategic military installations.

3. The Nike Ajax used only high explosive warheads. The Hercules missles used primarily nuclear warheads, but were capable of being fitted with high explosive warheads.

4. Among the substances used or stored on Nike sites were liquid missile fuel (JP-4); starter fluids (UDMH, aniline, and furfuryl alcohol); oxidizer (IRFNA); hydrocarbons (motor oil, hydraulic fluid, diesel fuel, gasoline, heating oil); solvents (carbon tetrachloride, trichloroethylene, trichloroethane, stoddard solvent); and battery electrolyte.

5. In general, the missile fuels and oxidizers were carefully controlled. Releases to the environment were confined to IRFNA and very small quantities of the other liquids. With the close of the Nike Ajax system in 1964, the use of liquid fuels was discontinued.

6. The quantities of materials disposed of and procedures for disposal are not documented in published reports. Virtually all information concerning the potential for contamination at Nike sites is confined to personnel who were assigned to Nike sites.

7. There appeared to be no systematic regional variation in procedures or disposal practices. Variations in procedures and disposal did result

from battalion-specific practices and adaptations to permafrost conditions.

8. Most Nike sites were equipped with sumps for disposing of liquid wastes. Any liquid disposed of in such sumps was allowed to soak into the ground. Alternatively, temporary storage and offsite disposal were used to handle liquid waste at some sites.

9. Of the materials disposed of at Nike sites, chlorinated organic solvents present the highest potential for residual contamination. At some sites the possibility of hydrocarbon, lead, or nitrate contamination may exist.

10. During deactivation most hardware was shipped to depot-level supply points. There were reportedly instances where excess materials were disposed of on or near the site itself at closure. There was reportedly no routine site decontamination.

9.0 REFERENCES

Brady, N.C. 1974. The Nature and Properties of Soils. Eighth Edition. MacMillan Publishing Co., Inc. New York, N.Y.

Burgess, E. 1957. Guided Weapons. MacMillan Company, New York.

Cagle, M.T. 1959. Historical Monograph: Development, Production, and Deployment of the Nike Ajax Guided Missile System, 1945-1959. U.S. Army Ordnance Missile Command (AOMC), Redstone Arsenal, Ala.

Cagle, M.T. 1973. Untitled Report on the Evolution of the Nike Hercules Weapon System. U.S. Army Missile Command (MICOM) Historical Office, Redstone Arsenal, Ala.

Environmental Science and Engineering, Inc. (ESE). 1982. Research and Development Services: Methods Development. Report No. DRXTH-TE-CR-82165. Gainesville, Fla.

Mabey, W.R., Smith, J.H., Podoll, R.T., Johnson, H.L., Mill, T., Chou, T.W., Gates, J., Partridge, I.W., and Vandenberg, D. 1981. Aquatic Fate Process Data for Organic Priority Pollutants. EPA Contract Nos. 68-01-3867 and 68-03-2981.

Matthess, G. 1982. The Properties of Groundwater. John Wiley & Sons, New York, N.Y.

Ordway, F.I. and Wakeford, R.C. 1960. International Missile and Spacecraft Guide. McGraw-Hill, New York, N.Y.

Parson, N.A., Jr. 1962. Missiles and the Revolution in Warfare. Harvard University Press, Cambridge, Mass.

Secretary of Defense. 1959. Correspondence from Neil McElroy to Dwight D. Eisenhower Regarding Summary of Progress on Anti-Ballistic Missile Weapon System Program for Quarter Ending July 15, 1959.

Todd, D.K. 1980. Groundwater Hydrology. Second Edition. John Wiley & Sons, New York, N.Y.

U.S. Army. 1956. Procedures and Drills for the Nike I System. Department of the Army Technical Manual FM44-80. Washington, D.C.

U.S. Environmental Protection Agency. 1980. Water Quality Criteria Documents: Availability. Federal Register, 45 (231): 79318-79379.

U.S. Environmental Protection Agency. 1981. National Interim Primary Drinking Water Regulations. Code of Federal Regulations, Title 40, Part 141, pp. 309-354.

Yaniga, P.M. 1982. Alternatives in Decontamination for Hydrocarbon-Contaminated Aquifers. In: Ground Water Monitoring Review, Fall 1982, Volume 2, Number 4.

APPENDIX A

ADDITIONAL SOURCES CONSULTED

APPENDIX A

ADDITIONAL SOURCES CONSULTED

Anonymous, n.d. Appendix D. Site Construction and Deployment of CONUS (ARADCOM) Units (U): I-Converted Defense Sites, II-New Defense Sites.

Bell Telephone Laboratories, Inc. 1959. Nike Hercules Field Army System. Prepared for the Department of the Army, Project No. DA-516-04-008. Whippany, N.J.

Bell Telephone Laboratories, Inc. 1960. Cross-Country Nike Hercules: Antiaircraft, Surface-to-Surface, Anti-Short-Range Ballistic Missiles. Prepared for the Department of the Army, Contract No. DA-30-069-ORD-1082. Whippany, N.J.

Gay, J.H. 1956. A Simplified Doctrinal Study for Nike in Metropolitan Defense. Princeton University, Analytical Research Group Technical Report No. 16. Princeton, N.J.

Headquarters, U.S. Army Air Defense Center and Fort Bliss. 1964. The Story of Fort Bliss. El Paso, Tex.

Headquarters, U.S. Army Air Defense Center and Fort Bliss. Directorate of Industrial Operations, Missiles and Systems Branch. El Paso, Tex.

Headquarters, U.S. Army Air Defense Center and Fort Bliss. Directorate of Plans and Training:
(1) Plans and Operations Division
(2) Test and Evaluation Division
(3) Range Branch. El Paso, Tex.

NATO Maintenance and Supply Agency (NAMSA). Nike Training Center, Course Development and Organization Branch. Headquarters, U.S. Army Air Defense Center and Fort Bliss. El Paso, Tex.

National Personnel Records Center. National Archives and Records Service. Directory of Military Personnel and Related Records. St. Louis, Mo.

North American Air Defense Command (NORAD), Headquarters. History Office, Colorado Springs, Colo.

North American Air Defense Command (NORAD). Miscellaneous Maps of the Air Defense Network. Colorado Springs, Colo.

U.S. Army Air Defense School, Directorate of Training Development. Patriot/Hercules Division, Headquarters, U.S. Army Air Defense Center and Fort Bliss. El Paso, Tex.

U.S. Army Air Defense School, Directorate of Training and Doctrine. Hercules/Patriot Department, Headquarters, U.S. Army Air Defense Center and Fort Bliss. El Paso, Tex.

U.S. Army, Center for Military History. Carlisle Barracks, Pa.

U.S. Army Corps of Engineers (COE). 1977. Agencies List of July 1, 1977.

U.S. Army Corps of Engineers (COE). District Offices.
(1) Real Estate Division, Audit and Management Disposal Branches, Omaha, Nebr.;
(2) Real Estate Division, Louisville, Ky.;
(3) Real Estate Division, Management and Disposal Branch, Sacramento, Calif.;
(4) Real Estate Division, Management and Disposal Branch, New York, N.Y.;
(5) Real Estate Division, Audit Branch, Jacksonville, Fla.;
(6) Real Estate Division, Audit Branch, Los Angeles, Calif.;
(7) Real Estate Division, Plans and Contracts Branch, Seattle, Wash.

U.S. Army Environmental Hygiene Agency (USAEHA). 1966. Report of Special Study No. 5299R89-66-67, X-Ray Hazards, Nike Hercules High Power Acquisition Radar (HIPAR). Edgewood Arsenal, Md.

U.S. Army Materiel Development and Readiness Command (DARCOM). Missile Command (MICOM) Representative. El Paso, Tex.

U.S. Army Toxic and Hazardous Materials Agency (USATHAMA). 1980. Historical Summary Report of Findings and Recommendations for Providence Defense Area, Nike Batteries: Battery 38, Bristol, Rhode Island; Battery 58, North Kingstown (Davisville), Rhode Island; Battery 79, Foster, Rhode Island; and Battery 99, North Smithfield, Rhode Island. Aberdeen Proving Ground, Md. Report No. A005.

APPENDIX B

LOCATIONS OF FORMER NIKE MISSILE SITES

Appendix B consists of two tables and a series of maps which can be used, individually or in conjunction with each other, to identify the locations of former Nike missile sites.

Appendix B-1 is a table of Nike missile locations compiled from information provided by Real Property Offices of the U.S. Army Corps of Engineers (CE). The table is organized by state and provides the CE site designation, location (as indicated in the CE records), and comments regarding whether or not the site is still Army real property (ARP). Where provided by CE, dates of excessing are given for sites that are not Army real property (NARP).

Appendix B-2 is a listing of Nike sites showing responsible units, periods of activity, and locations. This table was compiled from historical records obtained from the Military History Institute, Carlisle Barracks, Pa. for the years 1954 through 1974. The dates of operation and locations at which each military unit operated a Nike site were determined by reviewing individual annual listings. The letters AC in the Hercules closing date column indicate an active status as of the last year of record (1974). The remarks column gives additional locations at which the particular battery was listed, and the date such listing appeared. In some cases, these additional locations may represent a physical relocation of battery personnel. In most instances, they appear to represent alternative names for the same site.

While some Nike sites can be unambiguously located in both Appendix B-1 and Appendix B-2, this is often not possible. For example, Appendix B-2 uses town/county location names for the Pennsylvania sites that can not be readily correlated with the sites that Appendix B-1 lists as being in Philadelphia. This inconsistency is inherent in the source documents and can not be readily resolved. Despite the inability to completely correlate the information in Appendix B-1 with the information in Appendix B-2, each provides useful information not found in the other. The nature of the sources for both tables is such that the listings of Nike sites may be incomplete.

APPENDIX B

LOCATIONS OF FORMER NIKE MISSILE SITES

Appendix B consists of two tables and a series of maps which can be used, individually or in conjunction with each other, to identify the locations of former Nike missile sites.

Appendix B-1 is a table of Nike missile locations compiled from information provided by Real Property Offices of the U.S. Army Corps of Engineers (CE). The table is organized by state and provides the CE site designation, location (as indicated in the CE records), and comments regarding whether or not the site is still Army real property (ARP). Where provided by CE, dates of excessing are given for sites that are not Army real property (NARP).

Appendix B-2 is a listing of Nike sites showing responsible units, periods of activity, and locations. This table was compiled from historical records obtained from the Military History Institute, Carlisle Barracks, Pa. for the years 1954 through 1974. The dates of operation and locations at which each military unit operated a Nike site were determined by reviewing individual annual listings. The letters AC in the Hercules closing date column indicate an active status as of the last year of record (1974). The remarks column gives additional locations at which the particular battery was listed, and the date such listing appeared. In some cases, these additional locations may represent a physical relocation of battery personnel. In most instances, they appear to represent alternative names for the same site.

While some Nike sites can be unambiguously located in both Appendix B-1 and Appendix B-2, this is often not possible. For example, Appendix B-2 uses town/county location names for the Pennsylvania sites that can not be readily correlated with the sites that Appendix B-1 lists as being in Philadelphia. This inconsistency is inherent in the source documents and can not be readily resolved. Despite the inability to completely correlate the information in Appendix B-1 with the information in Appendix B-2, each provides useful information not found in the other. The nature of the sources for both tables is such that the listings of Nike sites may be incomplete.

APPENDIX B

LOCATIONS OF FORMER NIKE MISSILE SITES

The maps presented in Appendix B-3 show the locations of ARADCOM sites in CONUS as of 1968 and give certain information about the unit and equipment at each site. The top line in each box gives the CE designation for the property, such as LA-04. The second line is a military unit designation (for example, A/4/65 to indicate A Battery, 4th Battalion, 65th Artillery). Other items in the boxes describe certain equipment at the site, such as HIPAR for high-power acquisition radar, and HAWK for a Hawk missile battery. The other codes have not been identified. These maps were included in an annual historical summary report produced in 1968 and obtained from the NORAD History Office in Colorado Springs, Colo. Similar maps could not be located for other years.

APPENDIX B-1
LOCATIONS OF NIKE MISSILE SITES
IDENTIFIED BY THE U.S. ARMY CORPS OF ENGINEERS

State	Designation	Location	Comments
Alaska	02-701	Fairbanks	NARP
	02-714	Fairbanks	ARP
	02-709	Fairbanks	ARP (CE)
	02-731	Fairbanks	ARP (CE)
	02-711	Fairbanks	ARP (in pool for Native Corp.)
	02-725	Anchorage	NARP
	02-695	Anchorage	NARP
California	LA 04	Mt. Gleason	NARP
	LA 09	Mt. Disappointment	NARP
	LA 14	Whittier Narrows	NARP
	LA 29	Brea	NARP
	LA 32	Los Alamitos	NARP
	LA 40	Lakewood	NARP
	LA 43	Ft. MacArthur	*
	LA 55	Point Vicente	NARP
	LA 57	Redondo Beach	*
	LA 70	Playa Del Rey	*
	LA 73	Playa Del Rey	*
	LA 78	Santa Monica Mtns.	NARP
	LA 88	Oak Mtn.	NARP
	LA 94	Los Pinetos Mtn.	*
	LA 95	Los Angeles Area	NARP
	LA 96	Metro LA Area	NARP
	LA 98	Van Nuys (Magic Mtn.)	NARP
		Balsa Chica	NARP
	SF 25	Oakland	NARP excessed 1964
	SF 31	Oakland	NARP excessed 1975
	SF 37	Alvarado	NARP excessed 1963
	SF 51	Rockaway Beach	NARP excessed 1979
	SF 59	San Francisco	NARP excessed 1972
	SF 87	Ft. Barry	*
	SF 88	Ft. Cronkhite	*
	SF 89	San Francisco	NARP excessed 1963
	SF 91	San Francisco	NARP excessed 1963
	SF 93	San Rafael	NARP excessed 1972
	Site 61-R	San Francisco	NARP excessed 1961
	AAA Batt 12	Berkeley	NARP excessed 1959
	SF 08-09	Berkeley	NARP excessed 1972
	T 53	Fairfield	NARP
	T 10	Elmira	ARP
	T 33	Vocaville	NARP
	T 86	Fairfield	NARP (19 ha), ARP (28 ha leased)

APPENDIX B-1
LOCATIONS OF NIKE MISSILE SITES
IDENTIFIED BY THE U.S. ARMY CORPS OF ENGINEERS

State	Designation	Location	Comments
Connecticut	BR 04	Ansonia	*
	BR 15	New Haven	NARP
	BR 17	Bridgeport	NARP
	BR 65	Bridgeport	NARP
	BR 73	Westport	NARP
	BR 94	Monroe	NARP
	HA 08	East Windsor	*
	HA 25	Hartford	NARP
	HA 36	Portland	NARP
	HA 48	Cromwell	NARP
	HA 67	Plainville	NARP
	HA 85	Simsbury	NARP
Florida	12005	Richmond AFB	NARP trans to USAF
	12150	Broward Co.	1 parcel ARP, 1 parcel NARP
	12159	Dade Co.	NARP - sold by GSA
	12164	Dade Co.	NARP - sold by GSA
	12165	Monroe Co.	NARP - transferred to Navy
	12170	Dade Co.	NARP - sold by GSA
	12180	Dade Co.	NARP - transferred to Nat'l. Park Svc.
	12190	Dade Co.	NARP - sold by GSA
	12195	Miami	ARP(permitted to INS refuge)
	12199	Monroe Co.	NARP - transferred to Navy
	12201	Monroe Co.	NARP - transferred to Navy
	12205	Monroe Co.	NARP - transferred to Navy
	12209	Monroe Co.	NARP - transferred to Navy
	12010	Monroe Co.	NARP - transferred to Navy
Georgia	TU 79	Albany	NARP
	R 128	Jeffersonville	NARP
	R 88	Byron	NARP
	TU 28	Sylvester	NARP
Hawaii	Site 1	Waialua, Oahu	NARP
	Site 2	Kahuku, Oahu	ARP
	Site 3 & 4	Hawaii Kai, Oahu	NARP
	Site 5 & 6	Makakilo, Oahu	ARP Excessed to GSA on 6 June 79
Idaho	05	Mountain Home AFB	NARP
	79	Mountain Home AFB	NARP

APPENDIX B-1
LOCATIONS OF NIKE MISSILE SITES
IDENTIFIED BY THE U.S. ARMY CORPS OF ENGINEERS

State	Designation	Location	Comments
Illinois	C 40	Chicago	NARP
	C 03	Chicago	NARP
	C 44	Chicago	NARP
	C 80	Arlington	(ARP (USAR Center)
	C 41	Chicago	NARP
	C 47	Porter	NARP
	C 49	Homewood	*
	C 51	Alsip	NARP (3.0 ha leased ARP)
	C 54	Orland Park	*
	C 61	DuPage Co.	ARP (leased)
	C 70	Naperville	NARP
	C 72	Addison	*
	C 80	Arlington Hts.	*
	C 84	Palatine	NARP
	C 93	Northfield	NARP
	C 92-94	Libertyville	NARP
	C 98	Ft. Sheridan	*
	SL 90	Grafton	NARP
	SL 40	Monroe Co.	NARP
	SL 10	Madison, CO	NARP
Indiana	C 48	Gary	NARP
	C 45	Gary	NARP
	C 46	Munster	NARP
	C 32	Porter Co.	NARP
	CD 63	Dearborn	NARP
Iowa	10	Council Bluffs	NARP
Kansas	KC 80	Leavenworth Co.	NARP 3/26/58-3/21/73
	KC 60	Johnson Co.	NARP 3/26/58-7/29/69
	KC HQ	Olathe	NARP 9/17/58-4/1/69
	SC 01	Ottawa	NARP 3/10/59-2/2/62
	SC 50	Saline Co.	NARP 3/10/59-2/2/62
Louisiana	BD 10	Bellevue	1960-1967
	BD 50	Stonewall	1960-1967
Maine	LO 13	Caswell	NARP
	LO 31	Linestone	NARP
	LO 58	Presque Isle	NARP
	LO 85	Connor	NARP

APPENDIX B-1
LOCATIONS OF NIKE MISSILE SITES
IDENTIFIED BY THE U.S. ARMY CORPS OF ENGINEERS

State	Designation	Location	Comments
Maryland	W 54	Pomonkey	NARP to Navy
	BA 03	Phoenix	37 ac. to Balt Co., 1976
	BA 09	Fork	Declared Excess
	W 25	Davidsonville	NARP
	W 26	Annapolis	NARP deeded to Navy
	BA 30,31	Chestertown	NARP deeded to Kent Co.
	W 45	Waldorf	NARP to Navy
	W 34	Suitland	NARP trans. to Smithsonian Institute
	W 35	Croom	*
	W 44	Waldorf	Declared Excess
	BA 79	Granite	NARP to GSA and State
	W 92	Rockville	NARP to GSA
	W 93	Fed. Regional Ctr.	NARP
	W 94	Laytonsville	NARP to Navy & private
	BA 92	Baltimore	NARP to GSA and USAR
	BA 43	Anne Arunded Co.	NARP
	W 36	Brandywine	NARP
	BA 18	Army Chem. Center	*
Mass.	B 03	Reading	NARP
	B 05	Danvers	NARP
	B 15	Beverly	NARP
	B 17	Nahant	NARP
	B 36	Weymouth	NARP
	B 37	Quincy	NARP
	B 38	Hingham	NARP
	B 63	Needham	NARP
	B 73	Lincoln	NARP
	B 84	Burlington	NARP
	B 85	Bedford	NARP
	PR 19	Rehoboth	NARP
	PR 29	Swansea	NARP
	B 55	Blue Hills	*
Michigan	D 15	Selfridge AFB	NARP
	D 17	St. Clair Co.	NARP
	D 06	Utica	NARP
	D 14	Macomb Co.	NARP
	D 16	Selfridge AFB	ARP (leased)

APPENDIX B-1
LOCATIONS OF NIKE MISSILE SITES
IDENTIFIED BY THE U.S. ARMY CORPS OF ENGINEERS

State	Designation	Location	Comments
Michigan (Cont)	D 23-26	Wayne Co.	NARP
	D 51	Wayne Co.	NARP
	D 54-55	Riverview	NARP
	D 57	Newport NAS	*
	D 69	Detroit	*
	D 61	Wayne Co.	NARP
	D 86	Oakland Co.	NARP
	D 87	Oakland Co.	NARP
	D 58	Carleton	ARP (approx. .56 ha to be disposed of)
	D 97	Auburn Hts.	*
Minnesota	MS 40	Framington	NARP
	MS 90	Bethel	NARP
	MS 70	Minneapolis	NARP
	MS 20	St. Paul	NARP
Missouri	KC 10	Ray Co.	NARP 3/26/58-7/29/69
	KC 30	Cass Co.	ARP 3/26/58-11/21/72
	SL 60	Pacific	NARP
Nebraska	LI 01	Lincoln	NARP
	LI 50	Crete	NARP
	OF 60	Plattsmouth	NARP
	OF 10	Plattsmouth	*
New Mexico	WA 10	Walker AFB	NARP excessed 1961
	WA 50	Walker AFB	NARP excessed 1962
New Jersey	NYD 80	Morristown	Declared Excess
	PH 58	Swedesboro	--
	NYD 60	S. Amboy	2AC ARP
	NYD 65	S. Plainfield	NARP
	NYD 54	Holmdel	NARP
	PH 41/43	Glassboro	Declared Excess
	NYD 93	Mahwah	Declared Excess
	PH 32	Marlton	NARP
	NYD 73	Summit	NARP
	NYD 88	Mt. View	NARP
	PH 23/25	Mt. Holly	NARP
	PH 49	Richwood	NARP

APPENDIX B-1
LOCATIONS OF NIKE MISSILE SITES
IDENTIFIED BY THE U.S. ARMY CORPS OF ENGINEERS

State	Designation	Location	Comments
New York	NYD 49	Ft. Tilden	*
	NYD 04/05	Orangetown	20 AC ARP remains
	NYD 25	Brookhaven	Some ARP remains
	NYD 99	Ramapo	NARP
	NYD 20	Huntington	NARP
	NYD 24	Babylon	NARP
	NYD 09	White Plains	NARP
	NYD 23	Oyster Bay	NARP
	NYD 30	Lido Beach	NARP
	NF 03	Lewiston	NARP
	BU 09	Buffalo	NARP
	NF 16	Cambria	NARP
	BU 18	Lancaster	NARP
	BU 34/35	Aurora	NARP
	NB, NF 41	Grand Island	NARP
	BV 51/53	Hamburg	NARP
	NY 56	Ft. Hancock	*
	NY 15	Ft. Slocum	*
Ohio	CD 46	Clermont Co.	ARP (3.6 ha leased, remainder NARP)
	CL 67	Cleveland	NARP
	CL 48	Cuyahoga Co.	NARP
	CL 69	Cuyahoga Co.	ARP (5.5 ha leased, remainder NARP)
	CL 13	Lake Co.	NARP
	CD 27	Wilmington	*
	CD 78	Oxford	*
	CL 02	Cleveland	*
	CL 11	Painsville	*
	CL 34	Cleveland	*
	CL 59	Parma	*
Pennsylvania	PI 02	Rural Ridge	NARP, to State, DOT
	PI 03	Indianda	Declared Excess
	PI 36	Irwin	NARP to GSA
	PI 25	Murrysville	*
	PI 37	Hermine	NARP sold 1976
	PI 43	Elrama	ARP
	PI 52	Hickman	*
	PI 62	Bryant	*
	PI 71	Corapolis	NARP
	PI 92	Allegheny Co.	USARC
	PI 93	Allegheny Co.	USARC
	PH 07	Northampton	NARP

APPENDIX B-1
LOCATIONS OF NIKE MISSILE SITES
IDENTIFIED BY THE U.S. ARMY CORPS OF ENGINEERS

State	Designation	Location	Comments
Pennsylvania (Cont)	PH 15	Bristol	USARC
	PH 67	Upper Chichester	NARP
	PH 75/78	Edgemont	USARC
	PH 82	Chester Co.	NARP
	PH 91	Montgomery Co.	NARP
	PH 97/99	Warrington	USARC
Rhode Island	PR 99	N. Smithfield	NARP
	PR 38	Bristol	NARP
	PR 58	N. Kingston	NARP
	PR 69	Coventry	NARP
	PR 79	Foster	NARP
South Dakota	EE 40	Ellsworth AFB	NARP
	E 20	Ellsworth AFB	NARP
	E 40	Ellsworth AFB	NARP
	D 70	Ellsworth AFB	NARP
Texas	BG 40	Elroy	1959-1981
	BG 80	Austin	1959
	DFWDA	Duncanville	
	DF 1	Denton	
	DF 50	Alvarado	1958-1973
	DF 20	Terrell	1958-1971
	DY-10	Abilene	1960-1968
	DY-50	Abilene	1960-1968
	DF 70	Ft. Walters	Mineral Wells
Virginia	W 83	Herndon	*
	W 64	Lorton	NARP
	W 74	Fairfax	Declared Excess
	N 36	Virginia Beach	NARP - GSA
	N 63	Suffolk	NARP
	N 93	Hampton	USARC
	N 02	Hampton	
	N 58	Chesapeake	
	W 75	Isle of Wright Co.	
	N 85	Newport News	
	N 52	Norfolk	
	N 25	Ft. Story	*
	N 75	Smithfield	*

APPENDIX B-1
LOCATIONS OF NIKE MISSILE SITES
IDENTIFIED BY THE U.S. ARMY CORPS OF ENGINEERS

State	Designation	Location	Comments
Washington	F 07	Spokane	ARP (12 ha leased, remainder NARP)
	F 37	Spokane	ARP (leased)
	F 45	Spokane	NARP
	F 87	Spokane	NARP
	S 03	Seattle	ARP (17 ha leased, remainder NARP)
	S 13-14	Redmond	ARP (12 ha leased, remainder NARP)
	S 20	Seattle	NARP
	S 32-33	Seattle	NARP
	S 43	Midway	NARP (10 ha ARP)
	S 61	Vashon	NARP
	S 62	Bremerton	NARP
	S 81	Poulsbo	NARP
	S 82	Winslow	NARP (2 ha ARP)
	S 92	Kingston	NARP
	H 06	Saddle Mt.	*
	H 12	Othello	*
	H 52	Rattlesnake Mt.	*
	H 83	Priest Rapids	*
Wisconsin	M 02	River Hills	NARP
	M 20	Milwaukee	NARP
	M 42	Cudahy	NARP
	M 54	Milwaukee	NARP
	M 64	Muskego	NARP
	M 74	Muskego	NARP
	M 86	Menomonee Falls	NARP
	M 96	Milwaukee	ARP (leased)

SOURCE: CE Real Property Records

* Site not included in CE records. Information from secondary sources.
NARP = Not Army Real Property
ARP = Army Real Property

Appendix B-2. Nike Missile Sites

Unit	Battery	Ajax		Hercules		Location	Remarks
5th Arty/3rd Btn (24th Btn)	HQ	1955	1958	1959	AC	Fort Banks, Mass.	Rehoboth (1964); Coventry, R.I. (197[illegible]
	A	1955	1958	1959	1969	Nahaut, Mass.	Lincoln (1957); Windsor, Conn. (1966[illegible]
	B	1955	1958	1959	1964	Reading, Mass.	Bedford (1957); Fort Duvall (1962)
	C	1955	1958	1959	AC	Bluehill, Mass.	Burlington (1957); Bristol, R.I. (1963)
	D	1955	1958	1959	AC	Needham, Mass.	Danvers (1957)
52nd Arty/3rd Btn (514th Btn)	HQ	1955	1958	1959	1962	Quincy, Mass.	
	A	1955	1958	1959	1962	Lincoln, Mass.	Bingham (1957)
	B	1955	1958	1959	1962	Burlington, Mass.	Blue Hill (1956); Burlington (1958); Nahant (1960)
	C	1955	1958	1959	1962	Quincy, Mass.	
	D	1955	1958	1959	1962	Fort Duvall, Mass.	
57th Arty/1st Btn (605th Btn)	HQ	1956	1960	--	--	Fort Devens, Mass.	
	A	1957	1960	--	--	Beverly, Mass.	
	B	1956	1960	--	--	Danvers, Mass.	
	C	1956	1959	--	--	Bingham, Mass.	
	D	1956	1960	--	--	Bedford, Mass.	Reading (1957)
56th Arty/4th Btn (739th Btn)	HQ	1956	1958	1959	1963	Rehoboth, Mass.	
	B	1956	1958	1959	1963	Swansea, Mass.	
	C	1956	1958	1959	1963	N. Smithfield, R.I.	Bristol (1961)
	D	1956	1958	1959	1963	Foster, R.I.	N. Smithfield (1962)
68th Arty/4th Btn (751st Btn)	HQ	1956	1959	1960	1962	Coventry, R.I.	
	A	1956	1959	1960	1962	N. Kingston, R.I.	
	C	1956	1959	1960	1962	N. Smithfield, R.I.	
	D	1956	1959	1960	1962	Foster, R.I.	

Unit	Battery	Ajax		Hercules		Location	Remarks
55th Arty/1st Btn (66th Btn)	HQ	1955	1960	--	--	Fort Totten, N.Y.	
	A	1955	1960	--	--	Orangeburg, N.Y.	Long Island (1958)
	B	1955	1960	--	--	Kensico, N.Y.	
	C	1955	1960	--	--	Hicksville, N.Y.	
65th Arty/2nd Btn (483rd Btn)	HQ	1955	1958	1959	AC	Camp Kilmer, N.Y.	Van Nuys, Calif. (1973)
	A	1955	1958	1959	AC	Darlington, N.J.	Summit Watching (1958); Palmdale, Calif. (1973)
	B	1955	1958	1959	AC	S. Plainfield, N.J.	Malibu, Calif. (1973)
	C	1955	1958	1959	AC	Livingston, N.J.	Chatsworth, Calif. (1973)
	D	1955	1958	1959	1960	Lk. Pakanack, N.J.	
51st Arty/3rd Btn (505th Btn)	HQ	1955	1957	1958	1972	Fort Tilden, N.Y.	Fort Hancock, N.J. (1964); Highland, N.J. (1968)
	A	1956	1957	1958	1972	New York, N.Y.	Long Island (1957); Farmingdale (1963); S. Amboy, N.J. (1964); Fort Tilden (1963)
	B	1955	1957	1958	1964	New York, N.Y.	Fort Tilden (1963)
	C	1955	1957	1958	1972	Lido Beach, N.Y.	Fort Totten (1961); Fort Hancock (1964
	D	1957	1957	1958	1970	Brookhaven, N.Y.	Holmdel, N.J. (1964)
71st Arty/4th Btn (526th Btn)	HQ	1955	1959	1960	1964	Fort Hancock, N.J.	
	A	1955	1959	1960	1964	S. Amboy, N.J.	
	B	1955	1959	1960	1964	Holmdel, N.J.	Leonard Chapel Hill (1957); S. Plainesville (1961)
	C	--	--	1962	1964	Fort Hancock, N.J.	
	D	1955	1959	1960	1964	Holmdel, N.J.	
7th Arty/5th Btn (737th Btn)	HQ	1956	1958	1959	1969	Fort Tilden, N.Y.	Tappan (1964)
	A	1957	1958	1959	1969	Orangeburg, N.Y.	Fort Tilden (1964, 1968); Orangeburg (1967)
	B	1957	1958	1959	1969	Darlington, N.J.	Franklin (1963, 1968); Darlington (1967)
	C	1957	1958	1959	1964	Spring Valley, N.Y.	Livingston, N.J. (1960)
	D	1957	1958	1959	1961	Holmdel, N.J.	Fort Hancock (1959); Fort Totten, N.Y. (1960)

Unit	Battery	Ajax		Hercules		Location	Remarks
43rd Arty/3rd Btn	HQ	--	--	1959	AC	Lumberton, N.J.	Pedricktown (1962, 1968); Edgemont (1964
	A	--	--	1962	AC	Lumberton, N.J.	Clementon (1963, 1969); Pedricktown (1967)
	B	--	--	1962	AC	Swedesboro, N.J.	
	C	--	--	1962	1967	Lumberton, N.J.	Edgemont (1965)
55th Arty/4th Btn	HQ	--	--	1965	1967	Fort Totten, N.Y.	
244th Arty/1st Btn (N.Y. ARNG)		1960	1963	1964	AC	New York, N.Y.	Listed as Pa. ARNG in 1966
245th Arty/1st Btn (N.Y. ARNG)		1960	1964	--	--	New York, N.Y.	
212th Arty/1st Btn (N.Y. ARNG)		1960	1964	--	--	New York, N.Y.	
254th Arty/1st Btn (N.Y. ARNG)		1960	1962	1963	1966	New York, N.Y.	Listed as active under N.J. ARNG in 1972-1973
3rd Arty/5th Btn (74th Btn)	HQ	1956	1959	1960	1963	West View, Pa.	
	A	--	--	1961	1963	West View, Pa.	
	B	--	--	1960	1963	Caraopolis, Pa.	
	C	--	--	1961	1963	Dorseyville, Pa.	
	D	--	--	1960	1963	Finleyville, Pa.	
59th Arty/2nd Btn (176th Btn)	HQ	1955	1958	1959	1965	Maple, Pa.	Edgemont (1964)
	A	1955	1958	1959	1965	Valley Forge, Pa.	Paoli (1967); Philadelphia (1961); Warrington (1963)
	B	1955	1958	1959	1965	Gradyville, Pa.	Edgemont (1957, 1964)
	C	1955	1958	1959	1964	Buckman, Pa.	Chester (1957)
	D	1955	1958	1959	1964	Pennsgrove, N.J.	Swedesboro (1957)

Unit	Battery	Ajax		Hercules		Location	Remarks
60th Arty/3rd Btn (506th Btn)	HQ	1956	1958	1959	1961	Philadelphia, Pa.	
	A	1956	1958	1959	1961	Philadelphia, Pa.	
	B	1956	1958	1959	1961	Philadelphia, Pa.	
	C	1956	1958	1959	1961	Philadelphia, Pa.	
	D	1956	1958	1959	1961	Philadelphia, Pa.	
166th Arty/2nd Btn (Pa. ARNG)		1960	1963	1964	1969	Philadelphia, Pa.	
166th Arty/3rd Btn (Pa. ARNG)		1960	1963	--	--	Philadelphia, Pa.	
254th Arty/2nd Btn (N.Y. ARNG)		1960	1963	--	--	Philadelphia, Pa.	
112th Arty/7th Btn (N.J. ARNG)		--	--	1967	1971	Philadelphia, Pa.	
1st Arty/3rd Btn (1st Btn)	HQ	1955	--	1960	AC	Fort Irwin, Pa.	Pittsburgh (1959); Oakdale (1972)
	B	--	--	1961	AC	Sewickley, Pa.	Fort Irwin (1963); Hermine (1968)
	C	--	--	1961	1969	N. Huntington, Pa.	Fort Irwin (1963)
	D	--	--	1960	AC	Elizabeth, Pa.	Fort Irwin (1963); El Rana (1968)
6th Arty/6th Btn (509th Btn)	HQ	1955	1958	1959	1960	Pittsburgh, Pa.	
	A	1955	1958	1959	1960	Coraopolis, Pa.	
	B	1955	1958	1959	1960	Bridgeville, Pa.	
	C	1955	1958	1959	1960	Finleyville, Pa.	
	D	1955	1958	1959	1960	Elizabeth, Pa.	
176th Arty/2nd Btn (Pa. ARNG)		1960	1963	1964	1973	Pittsburgh, Pa.	
176th Arty/1st Btn (Pa. ARNG)		1960	1963	--	--	Pittsburgh, Pa.	

Unit	Battery	Ajax		Hercules		Location	Remarks
(13th Btn)	HQ	1956	1960	--	--	Orland Park, Ill.	
	A	1956	1960	--	--	Naperville, Ill.	
	C	1956	1960	--	--	LaGrange, Ill.	
	D	1956	1960	--	--	Palatine, Ill.	
52nd Arty/4th Btn	HQ	1956	1958	1959	1960	Chicago, Ill.	
(49th Btn)	A	1956	1958	1959	1960	Wheeler, Ind.	Hammond (1957); Homewood, Ill. (1959)
	B	1956	1958	1959	1960	Chicago, Ill.	
	C	1956	1958	1959	1960	Libertyville, Ill.	Munster, Ind. (1957); Chicago (1959)
	D	1956	1958	1959	1960	Wheeler, Ind.	Hedgewick, Ill. (1957); Chicago, Ill. (
517th Arty/1st Btn	HQ	1955	1959	1960	1961	Fort Sheridan, Ill.	
(78th Btn)	A	1956	1959	--	--	Libertyville, Ill.	
	B	1955	1959	--	--	Libertyville, Ill.	
	C	1958	1959	1960	1961	Fort Sheridan, Ill.	
	D	1956	1959	1960	1961	Arlington Hts., Ill.	Northfield (1959)
60th Arty/1st Btn (79th Btn)	HQ	1957	1958	1959	AC	Gary, Ind.	Munster (1969); Arlington Hts., Ill. (1971)
	A	1957	1958	1959	1971	Wheeler, Ind.	
	B	1957	1958	1959	AC	Chesterton, Ind.	Porter (1959, 1973)
	C	--	--	1960	1969	Gary, Ind.	Munster (1962)
	D	1957	1958	1959	1971	Gary, Ind.	Glen Park (1960); Chicago, Ill. (1965, 1968)
3rd Arty/6th Btn	HQ	1955	--	--	--	Fort Sheridan, Ill.	
(86th Btn)	A	1955	--	1962	--	Arlington Hts., Ill.	Homewood (1962); Chicago (1963)
	B	1955	--	1959	1965	Skokie, Ill.	Addison (1959)
	C	1955	--	1959	--	Argonne Laboratories, Ill.	Palatine (1959); Northfield (1961); Lemont (1962)
	D	1955	--	1963	--	Addison, Ill.	Northfield (1963)

Unit	Battery	Ajax		Hercules		Location	Remarks
57th Arty/2nd Btn	HQ	1955	--	--	--	Fort Sheridan, Ill.	
(485th Btn)	A	1955	--	--	--	Chicago, Ill.	Chicago (1962)
	B	1955	--	--	--	Chicago, Ill.	Northfield (1962)
	C	1955	--	--	--	Chicago, Ill.	
	D	1955	--	--	--	Hedgewick, Ill.	
59th Arty/3rd Btn	HQ	1956	1958	1959	1969	Prospect, Wis.	Milwaukee (1964)
(852nd Btn)	A	1956	1958	1959	1969	Prospect, Wis.	Milwaukee (1957)
	B	1956	1958	1959	1969	Waukesha, Wis.	Milwaukee (1957)
	C	1956	1958	1959	1969	Lannon, Wis.	Waukesha (1961); Chicago, Ill. (1965)
	D	1956	1958	1959	1969	Milwaukee, Wis.	Van Nuys, Calif. (1968)
60th Arty/2nd Btn	HQ	1959	1962	--	--	Orland Park, Ill.	
	A	1960	1962	--	--	Homewood, Ill.	
	C	1960	1962	--	--	Munster, Ind.	
	D	1959	1962	--	--	Lemont, Ill.	
562nd Arty/1st Btn	HQ	1955	1958	1959	1963	Fort George Meade, Md.	
(36th Btn)	A	--	--	1962	1963	Fort George Meade, Md.	
	B	--	--	1962	1963	Fort George Meade, Md.	
	D	--	--	1962	1963	Fort George Meade, Md.	
1st Arty/4th Btn	HQ	1955	1957	1958	AC	Edgewood Arsenal, Md.	
(54th Btn)	A	1955	1957	1958	AC	Granite, Md.	Sweet Air (1960); Gaithersburg (1968)
	B	1955	1957	1958	AC	Cromhardt, Md.	Granite (1960); }]]idsonville (1968); Fort Story, Va. (1971)
	C	1955	1957	1958	AC	Edgewood Arsenal, Md.	Edgewood Arsenal (1973)
	D	1955	1957	1958	AC	Kingsville (Fork), Md.	Irwin, Pa. (1963); Edgewood Arsenal (1964); Chestertown (1968)
51st Arty/4th Bto((	HQ	1955	1960	--	--	Fort Monroe, Va.	
(56th Btn)	A	1955	1960	--	--	Fort Hill, Va.	
	B	1955	1960	--	--	Spegalville, Va.	
	C	1955	1960	--	--	Camp Patrick, Va.	
	D	1955	1960	--	--	Carrollton, Va.	

Unit	Battery	Ajax		Hercules		Location	Remarks
71st Arty/1st Btn (71st Btn)	HQ	1956	1958	1959	1965	Fort Belvoir, Va.	Rockville, Md. (1964)
	A	1956	1958	1959	1965	Rockville, Md.	Pomonkey (1959); Rockville (1960)
	B	1956	1958	1959	1965	Dranesville, Va.	S. Plainfield (1960); Dranesville (1961); Waldorf (1962); Davidsonville Md. (1963)
	C	1956	1958	1959	1964	Lorton, Va.	
	D	1956	1958	1959	1964	Fairfax, Va.	Laytonville, Md. (1960)
562nd Arty/3rd Btn (75th Btn)	HQ	1955	1958	1958	1962	Andrews AFB, Md.	
	A	1955	1958	1958	1962	Washington, DC	Waldorf, Md. (1957); Mattawoman (1959); Pomankey (1960)
	B	1955	1958	1958	1962	Silver Springs, Md.	Marlboro (1957)
	C	1955	1958	1958	1962	Landover Hills, Md.	Waldorf (1957)
	D	1957	1958	1958	1962	LaPlata, Md.	Brandywine (1959)
5th Arty/4th Btn (602nd Btn)	HQ	1955	--	1959	1960	Army Chemical Center, Md.	
	A	1955	1959	--	--	Baltimore, Md.	
	B	1955	1959	--	--	Baltimore, Md.	
	C	1955	--	1959	1960	Baltimore, Md.	Gaithersburg (1956)
	D	1955	--	1959	1960	Baltimore, Md.	Naylor (1956); Rockville (1959)
70th Arty/2nd Btn (Md. ARNG)		1960	1963	--	--	Washington/Baltimore	
170th Arty/2nd Btn (Va. ARNG)			1960	1962	--	--	Washington/Baltimore
70th Arty/1st Btn (Md. ARNG)		1962	1963	1963	1973	Washington/Baltimore	
280th Arty/1st Btn (Va. ARNG)		1962	1963	1963	1964	Washington/Baltimore	

Unit	Battery	Ajax		Hercules		Location	Remarks
111th Arty/4th Btn (Va. ARNG)		1960	1963	1964	1973	Hampton Roads, Va.	A battery relocated to Washington/ Baltimore in 1964
111th Arty/5th Btn		1960	1962	--	--		
43rd Arty/1st Btn (10th Btn)	HQ	1957	--	1959	1966	Fairchild AFB, Wash.	
	C	--	--	1962	1966	Fairchild AFB, Wash.	
	D	--	--	1962	1966	Fairchild AFB, Wash.	
43rd Arty/2nd Btn (28th Btn)	HQ	1957	1958	1959	1966	Redmond, Wash.	Turner AFB, Ga. (1960)
	A	1957	1958	1959	1966	Fort Lawton, Wash.	Turner AFB, Ga. (1960)
	B	1957	1958	1959	1966	Fort Lawton, Wash.	Turner AFB, Ga. (1960)
	C	1957	1958	1959	1962	Fort Lawton, Wash.	
	D	1957	1958	1959	1962	Fort Lawton, Wash.	
52nd Arty/1st Btn (83rd Btn)	HQ	1955	1958	1959	1961	Camp Hanford, Wash.	
60th Arty/4th Btn (433rd Btn)	HQ	1956	1960	1961	1962	Fort Lawton, Wash.	
	A	1956	1960	1961	1962	Vashon Isl., Wash.	Seattle (1960)
	B	1957	1960	1961	1962	Lake Youngs, Wash.	Vashon Isl. (1960)
	C	1957	1960	1961	1962	Seattle, Wash.	
	D	1956	1960	1961	1962	Paulsboro, Wash.	Seattle (1957); Fort Lawton (1960)
4th Arty/4th Btn (513th Btn)	HQ	1958	1958	1959	1972	Paulsboro, Wash.	Fort Lawton (1964)
	A	1958	1958	1959	1965	Seattle, Wash.	Kent (1962); Redmond (1963)
	B	1958	1958	1959	1972	Seattle, Wash.	Vashon Isl. (1960); Kingston (1969)
	C	1958	1958	1959	1972	Seattle, Wash.	Kingston (1963)
	D	1958	1958	1959	1962	Fort Lawton, Wash.	
205th Arty/2nd Btn (Wash. ARNG)		1960	1964	1964	1973AC	Seattle, Wash.	
205th Arty/3rd Btn (Wash. ARNG)		1960	1964	--	--	Seattle, Wash.	

Unit	Battery	Ajax		Hercules		Location	Remarks
51st Arty/2nd Btn	HQ	1955	1959	1960	1971	Fort Baker, Calif.	
(9th Btn)	A	--	--	1962	1971	Fort Baker, Calif.	Fort Winfield Scott (1963); Sausalito (1969)
	B	--	--	1962	1971	Fort Baker, Calif.	Fort Cronkhite (1968)
	C	1955	1959	1960	1971	San Francisco, Calif.	San Rafase (1957); Fort Winfield Scott (1960); Berkeley (1963); San Rafase (1968)
	D	1955	1959	1960	1964	Angel Island, Calif.	San Francisco (1957)
67th Arty/4th Btn	HQ	1955	1958	1959	1963	Fort Cronkhite, Calif.	
(441st Btn)	A	1957	1958	1959	1963	San Bruno, Calif.	San Francisco (1960)
	B	1955	1956	--	--	Parks AFB, Calif.	San Francisco (1956)
	C	1955	1958	1959	1963	Benicia, Calif.	San Francisco (1960)
	D	1956	1958	1959	1963	Fort Cronkhite, Calif.	San Rafase (1960)
	HQ	1955	1958	--	--	San Francisco, Calif.	Fort Mott, N.J.
(738th Btn)	A	1955	1958	--	--	San Francisco, Calif.	Fort Mott, N.J.
	B	1955	1958	--	--	San Francisco, Calif.	Fort Dix, N.J.
	C	1955	1958	--	--	Fort Mott, N.J.	
	D	1955	1958	--	--	San Francisco, Calif.	Fort Dix, N.J.
61st Arty/4th Btn	HQ	1955	--	1962	1966	San Francisco, Calif.	Robins AFB, Ga. (1962)
(739th Btn)	A	1957	--	1962	1966	San Bruno, Calif.	Robins AFB, Ga. (1962)
	B	1955	--	1962	1966	San Francisco, Calif.	Robins AFB, Ga. (1962)
	C	1957	1958	--	--	San Francisco, Calif.	
	D	1955	1958	--	--	San Francisco, Calif.	
250th Arty/1st Btn (Calif. ARNG)		1960	1962	1963	1973AC	San Francisco, Calif.	
250th Arty/2nd Btn (Calif. ARNG)		1960	1962	--	--	San Francisco, Calif.	
65th Arty/4th Btn	HQ	1955	1957	1958	1972	Van Nuys, Calif.	
(551st Btn)	A	1955	1957	1958	1972	San Fernando, Calif.	Palmdale (1968)
	B	1955	1957	1958	1972	San Fernando, Calif.	Fort MacArthur (1964); Malibu (1968)
	C	1957	1957	1958	1972	San Fernando, Calif.	Fort MacArthur (1964); Van Nuys (1965); Chatsworth (1969)
	D	--	--	1962	1969	Van Nuys, Calif.	

Unit	Battery	Ajax		Hercules		Location	Remarks
57th Arty/3rd Btn (554th Btn)	HQ	1956	1958	1959	1964	Fort MacArthur, Calif.	
	B	1956	1958	1959	1964	Long Beach, Calif.	Fort MacArthur (1963)
	C	--	--	1962	1964	Fort MacArthur, Calif.	
	D	--	--	1962	1964	Fort MacArthur, Calif.	
56th Arty/1st Btn (933rd Btn)	HQ	1956	1959	1960	1969	Fort MacArthur, Calif.	Lang (1966)
	A	1956	1959	1960	1969	El Monte, Calif.	Puente Hills (1957); Pasadeha (1963); Van Nuys (1964); Newhall (1968)
	B	1956	1959	1960	1964	Santa Ana AFB, Calif.	Mt. Disappointment (1957); Pasadena (1958); Fort MacArthur (1962)
	C	1956	1959	1960	1964	Santa Ana AFB, Calif.	Mt. Gleason (1957); Van Nuys (1958); Pasadena (1963)
	D	1956	1959	1960	1969	Santa Ana AFB, Calif.	Van Nuys (1957, 1960); Pasadena (1958, 1961); Palmdale (1968)
251st Arty/4th Btn (Calif. ARNG)		1960	1963	1963	1973AC	Los Angeles, Calif.	
3rd Arty/4th Btn (18th Btn)	HQ	1957	1958	1959	1961	Detroit, Mich.	
	A	1957	1958	1959	1961	Detroit, Mich.	
	C	1957	1958	1959	1961	Commerce, Mich.	Milford (1959)
	D	1957	1958	1959	1961	Algonac, Mich.	Auburn Hts. (1958)
55th Arty/3rd Btn (85th Btn)	HQ	1955	1957	1958	1961	Fort Wayne, Ind.	
	A	1955	1957	1958	1961	Detroit, Mich.	
	B	1956	1957	1958	1961	Detroit, Mich.	
	C	1955	1957	1958	1961	Detroit, Mich.	Riverview (1958); Wyando Hts. (1959)
	D	1955	1958	--	--	Detroit, Mich.	
517th Arty/2nd Btn (504th Btn)	HQ	1955	1959	1960	1963	Detroit, Mich.	
	A	1955	1959	1960	1963	Detroit, Mich.	
	B	1955	1959	1960	1963	Riverview, Mich.	Newport (1957, 1961)
	C	1955	1959	1960	1963	Newport, Mich.	Detroit (1956); Dearborn (1957); Romulus (1959)
	D	1955	1959	1960	1963	Newport, Mich.	Commerce (1956); Carleton (1960); Detroit (1961)

Unit	Battery	Ajax		Hercules		Location	Remarks
517th Arty/3rd Btn (516th Btn)	HQ	1955	1958	1959	1972	Selfridge AFB, Mich.	
	A	--	--	1962	1972	Selfridge AFB, Mich.	Union Lake (1971)
	B	1955	1958	1959	1969	Unica, Mich.	Detroit (1963)
	C	--	--	1962	1970	Milford, Mich.	Union Lake (1963); Selfridge AFB (1969)
	D	1955	1958	1959	1964	Auburn Hts., Mich.	Algonac (1958); Milford (1961)
177th Arty/1st Btn (Mich. ARNG)		1960	1962	1963	1973AC	Detroit, Mich.	
177th Arty/2nd Btn (Mich. ARNG)		1960	1962	--	--	Detroit, Mich.	
55th Arty/2nd Btn (11th Btn)	HQ	1956	1958	1959	1966	Manchester, Conn.	New Britain (1964)
	A	1956	1958	1959	1966	Windsor, Conn.	
	B	1956	1958	1959	1964	Portland, Conn.	Ansonia (1961)
	C	1956	1958	1959	1964	Manchester, Conn.	
	D	--	--	1961	1964	Cromwell, Conn.	
51st Arty/1st Btn (34th Btn)	HQ	1956	1961	--	--	Plaineville, Conn.	
	A	1956	1961	--	--	Simsbury, Conn.	
	C	1956	1961	--	--	Cromwell, Conn.	
44th Arty/3rd Btn (741st Btn)	HQ	1957	1961	--	--	Fairfield, Conn.	
	A	1957	1961	--	--	Shelton, Conn.	
	C	1957	1961	--	--	Westport, Conn.	
	D	1957	1961	--	--	Plainville, Conn.	
56th Arty/3rd Btn (967th Btn)	HQ	1956	1958	1959	1961	West Haven, Conn.	
	A	1956	1958	1959	1961	Milford, Conn.	
	B	1956	1958	1959	1961	Fairfield, Conn.	Ansonia (1958)
	C	1956	1958	1959	1961	Westport, Conn.	Shelton (1958)
59th Arty/4th Btn (38th Btn)	HQ	1955	1958	1959	1971	Norfolk, Va.	Fort Story
	A	1955	1958	1959	1964	Norfolk, Va.	Carrollton (1960)
	B	1955	1958	1959	1965	Norfolk, Va.	Deep Fork (1963)
	C	1955	1958	1959	1965	Norfolk, Va.	Camp Patrick (1960)
	D	1955	1958	1959	1971	Norfolk, Va.	Fort Story (1970)

Unit	Battery	Ajax		Hercules		Location	Remarks
4th Arty/1st Btn	HQ	1955	1958	1959	1970	Fort Niagara, N.Y.	Lockport AFB (1964); Sanborn (1967)
(44th Btn)	A	1955	1958	1959	1964	Model City, N.Y.	Lancaster (1962)
	B	1955	1958	1959	1969	Cambria, N.Y.	
	C	1955	1958	1959	1964	Grand Island, N.Y.	
	D	1955	1958	1959	1964	Grand Island, N.Y.	
44th Arty/4th Btn (168th Btn)	HQ	1958	AC	--	--	Fort Bliss, Tex.	
68th Arty/1st Btn	HQ	1956	1958	1959	1961	Warren, Ohio	
(351st Btn)	A	1956	1958	1959	1961	Cleveland, Ohio	
	B	1956	1959	--	--	Cleveland, Ohio	
	C	--	--	1959	1961	Cleveland, Ohio	Warren (1960)
	D	--	--	1959	1961	Cleveland, Ohio	Warren (1960)
67th Arty/3rd Btn	HQ	1956	1958	1959	1961	Paynesville, Wis.	
(401st Btn)	A	1956	1958	1959	1961	River Hills, Wis.	Prospect (1958); Muskeegon (1960)
	B	1956	1958	1959	1961	Milwaukee, Wis.	
	D	1956	1958	1959	1961	Milwaukee, Wis.	Waukesha (1958)
62nd Arty/2nd Btn	HQ	1956	1958	1959	1962	Fort Niagara, N.Y.	
(465th Btn)	A	1956	1958	1959	1962	Millersport, N.Y.	
	C	1956	1958	1959	1962	Orchard Park, N.Y.	
	D	1956	1958	1959	1962	Hamburg, N.Y.	
52nd Arty/2nd Btn	HQ	1955	1958	1959	AC	Fort Bliss, Tex.	Homestead AFB, Fla. (1972)
(495th Btn)	A	--	--	1964	1972	Homestead AFB, Fla.	
	B	--	--	1962	1972	Homestead AFB, Fla.	
	C	--	--	1964	1972	Homestead AFB, Fla.	
	D	--	--	1964	1969	Homestead AFB, Fla.	
65th Arty/3rd Btn	HQ	1957	1959	1960	1971	Cleveland, Ohio	
(508th Btn)	A	1958	1959	1960	1971	Cleveland, Ohio	Painesville (1959)
	C	1957	1959	1960	1964	Cleveland, Ohio	Warren (1961)
	D	1957	1959	1960	1971	Cleveland, Ohio	Lordstown (1957)

Unit	Battery	Ajax		Hercules		Location	Remarks
67th Arty/2nd Btn (531st Btn)	HQ	1957	1958	1959	1961	Ellsworth AFB, Calif.	
61st Arty/3rd Btn (548th Btn)	HQ	1957	1958	1959	1966	Loring AFB, Maine	
	A	1957	1958	1959	1966	Coswell, Maine	
	B	1957	1958	1959	1965	Limestone, Maine	
	C	1957	1958	1959	1966	Caribou, Maine	
	D	1957	1958	1959	1964	Connor, Maine	
61st Arty/1st Btn (436th Btn)	HQ	1958	--	1959	AC	Travis AFB, Calif.	Presidio (1971)
	A	--	--	1963	AC	Travis AFB, Calif.	
	B	--	--	1963	AC	Travis AFB, Calif.	Fort Barry (1971, 1973)
	C	--	--	1971	1971	Travis AFB, Calif.	
7th Arty/4th Btn	HQ	--	--	1960	--	Bergstrom AFB, Tex.	
	A	--	--	1962	--	Bergstrom AFB, Tex.	Elroy (1963)
	B	--	--	1962	--	Bergstrom AFB, Tex.	Austin (1963)
43rd Arty/4th Btn	HQ	--	--	1959	1974	Fort Richardson, Alaska	
43rd Arty/6th Btn	HQ	--	--	1960	1966	Omaha AFB, Nebr.	
	A	--	--	1962	1966	Omaha AFB, Nebr.	Treynor (1963)
	B	--	--	1962	1966	Omaha AFB, Nebr.	Louisville (1963)
	C	--	--	1962	1966	Omaha AFB, Nebr.	Crete (1963)
	D	--	--	1962	1966	Omaha AFB, Nebr.	Davey (1963)
51st Arty/6th Btn	HQ	--	--	1960	AC	Mt. Home AFB, Idaho	Fort Bliss, Tex. (1967)
55th Arty/4th Btn	HQ	--	--	1965	1967	Fort Totten, N.Y.	
55th Arty/5th Btn	HQ	--	--	1959	1969	Olathe NAS, Kans.	
	A	--	--	1962	1965	Olathe NAS, Kans.	Lawson, Mo. (1963)
	B	--	--	1962	1965	Olathe NAS, Kans.	Pleasent, Mo. (1963)
	C	--	--	1962	1969	Olathe NAS, Kans.	Gardner (1963)
	D	--	--	1962	1969	Olathe NAS, Kans.	Fort Leavenworth (1963)

Unit	Battery	Ajax		Hercules		Location	Remarks
56th Arty/5th Btn	HQ	--	--	1959	1970	Wilmington, Ohio	Cincinnati (1961); Wilmington (1963)
	A	--	--	1962	1969	Wilmington, Ohio	Cincinnati (1967)
	B	--	--	1962	1965	Wilmington, Ohio	Felicity (1963)
	C	--	--	1962	1970	Wilmington, Ohio	Dillsboro (1963, 1968); Cincinnati (1967)
	D	--	--	1962	1965	Wilmington, Ohio	Oxford (1963)
62nd Arty/1st Btn	HQ	--	--	1959	1969	Scott AFB, Ill.	
	A	--	--	1962	1969	Scott AFB, Ill.	Marine (1963)
	B	--	--	1962	1969	Scott AFB, Ill.	Hecker (1963)
	C	--	--	1962	1969	Scott AFB, Ill.	Pacific, Mo. (1963)
	D	--	--	1962	1969	Scott AFB, Ill.	Pere Marquette (1964); Grafton (1968)
62nd Arty/4th Btn	HQ	--	--	1959	AC	Fort Bliss, Tex.	
68th Arty/3rd Btn	HQ	--	--	1959	AC	Minneapolis, Minn.	Snelling AFB (1964); Homestead AFB, Fl (1972)
	A	--	--	1960	1971	Roberts, Wis.	
	B	--	--	1960	1971	Farmington, Minn.	
	C	--	--	1960	1971	St. Bonifacius, Minn.	
	D	--	--	1960	1971	Bethel, Minn.	
333rd Arty/1st Btn	HQ	--	--	1964	1970	Fort Bliss, Tex.	
517th Arty/5th Btn	HQ	--	--	1960	1966	Dyess AFB, Tex.	
	A	--	--	1962	1966	Dyess AFB, Tex.	Abilene (1963)
	B	--	--	1962	1966	Dyess AFB, Tex.	Abilene (1963)
562nd Arty/2nd Btn	HQ	--	--	1959	AC	Eielson AFB, Alaska	Fort Wainwright (1964)
	A	--	--	1961	AC	Fort Wainwright, Alaska	Eielson AFB (1964, 1972)
	B	--	--	1961	AC	Fort Wainwright, Alaska	Eielson AFB (1964, 1972)
	C	--	--	1961	1970	Fort Wainwright, Alaska	Eielson AFB (1964)
	D	--	--	1961	1970	Fort Wainwright, Alaska	Eielson AFB (1964)

Unit	Battery	Ajax		Hercules		Location	Remarks
562nd Arty/4th Btn	HQ	--	--	1959	1969	Duncanville AFB, Tex.	
	A	--	--	1962	1965	Duncanville AFB, Tex.	Denton (1963)
	B	--	--	1962	1965	Duncanville AFB, Tex.	Terrell (1963)
	C	--	--	1962	1969	Duncanville AFB, Tex.	Alvarado (1963, 1968); Dallas (1967)
	D	--	--	1962	1969	Duncanville AFB, Tex.	Fort Wolters (1963, 1968); Dallas (1967
562nd Arty/5th Btn	HQ	--	--	1960	1966	Louisiana Ord. Plant (Shreveport), La.	
	A	--	--	1962	1966	Louisiana Ord. Plant (Shreveport), La.	Bellevue (1963)
	B	--	--	1962	1966	Louisiana Ord. Plant (Shreveport), La.	Stonewall (1963)

APPENDIX B-3

METROPOLITAN DEFENSE AREA MAPS

"NOTICE"

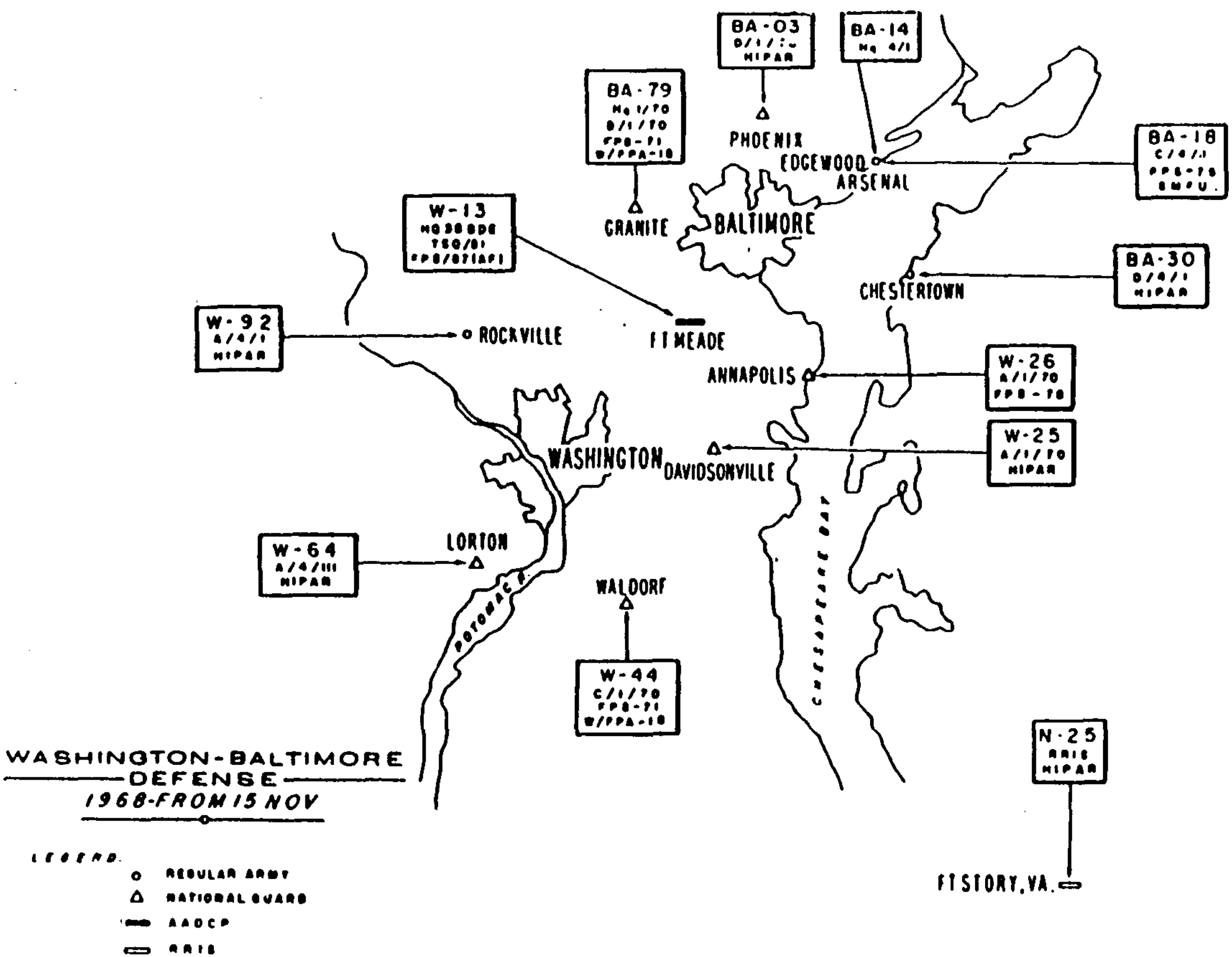
The documents contained in this Appendix have been reproduced from the best copies available. Although certain portions are illegible, this material is being released in the interest of making available as much information as possible.

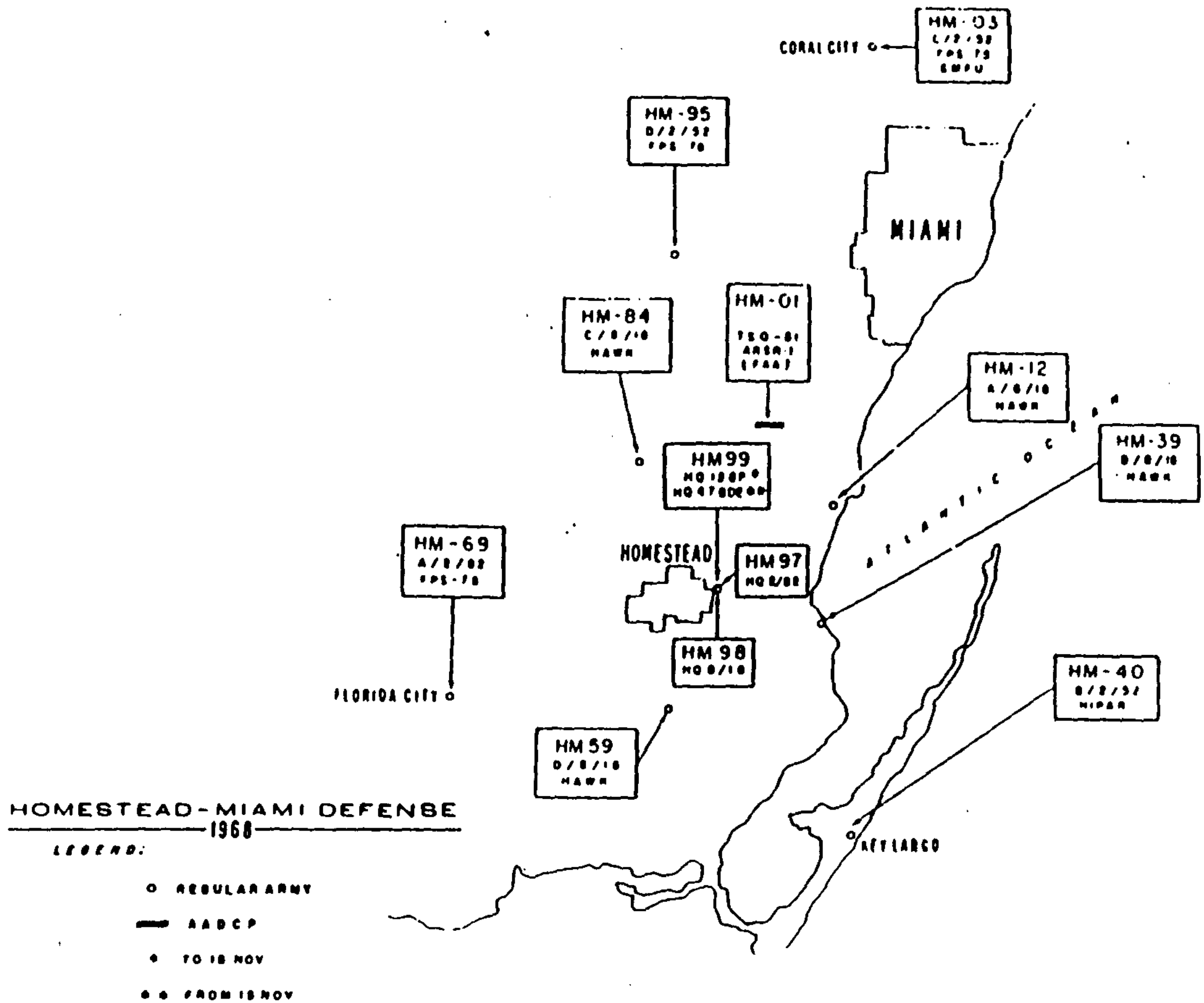
APPENDIX B-3

METROPOLITAN DEFENSE AREA MAPS

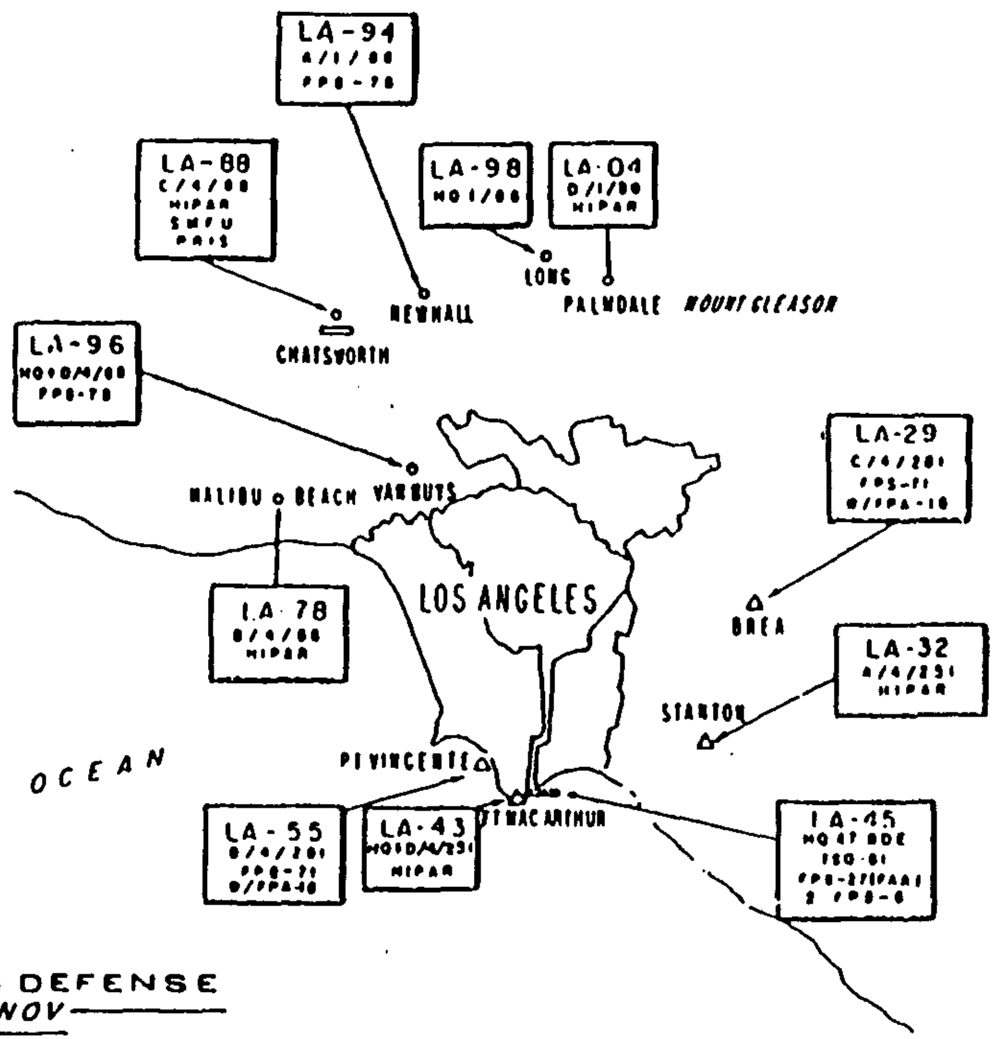
The maps presented in this section show the location of ARADCOM sites in CONUS as of 1968 and give certain information about the unit and equipment at each site. The top line in each box gives the COE designation for the property, such as LA-04. The second line is a military unit designation (for example, A/4/65 to indicate A battery, 4th Battalion, 65th Artillery). Other items in the boxes describe certain equipment at the site, such as HIPAR for high-power acquisition radar, and HAWK for a Hawk missile battery. The other codes have not been identified.

Personnel at the NORAD History Office in Colorado Springs, Colo., provided the maps presented, which were included in an annual historical summary report produced in 1968. Similar maps could not be located for other years.


BA-03
HIPAR
BA-14
BA-79
BA-18
BA-30
HIPAR
W-13
W-92
HIPAR
W-26
A/1/70
W-25
A/1/70
HIPAR
W-64
HIPAR
W-44
N-25
HIPAR
PHOENIX
EDGEWOOD ARSENAL
GRANITE
BALTIMORE
CHESTERTOWN
ROCKVILLE
FT MEADE
ANNAPOLIS
WASHINGTON
DAVIDSONVILLE
LORTON
WALDORF
POTOMAC R.
CHESAPEAKE BAY
FT STORY, VA.
WASHINGTON-BALTIMORE
DEFENSE
1968-FROM 15 NOV
LEGEND.
REGULAR ARMY
NATIONAL GUARD
AADCP

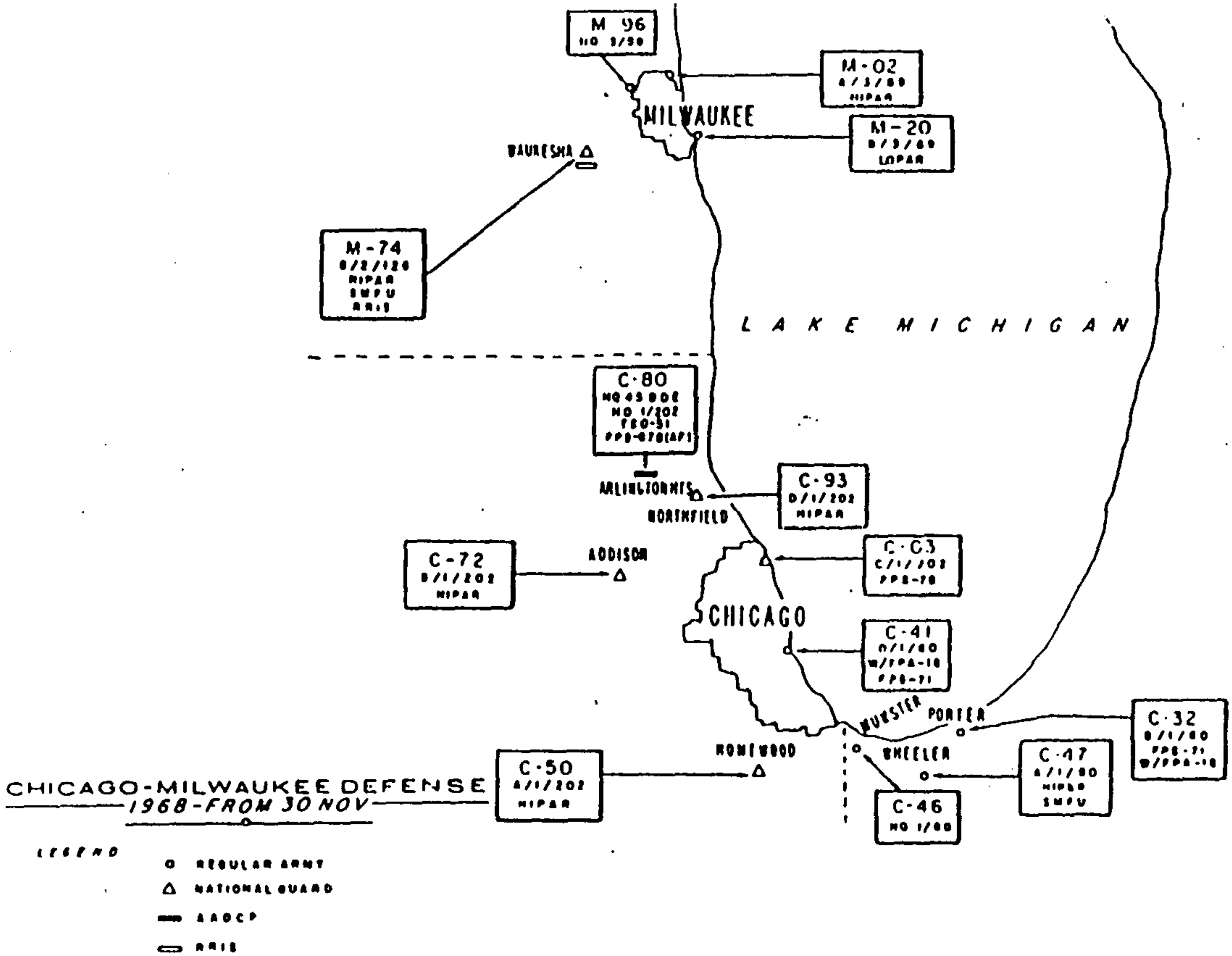


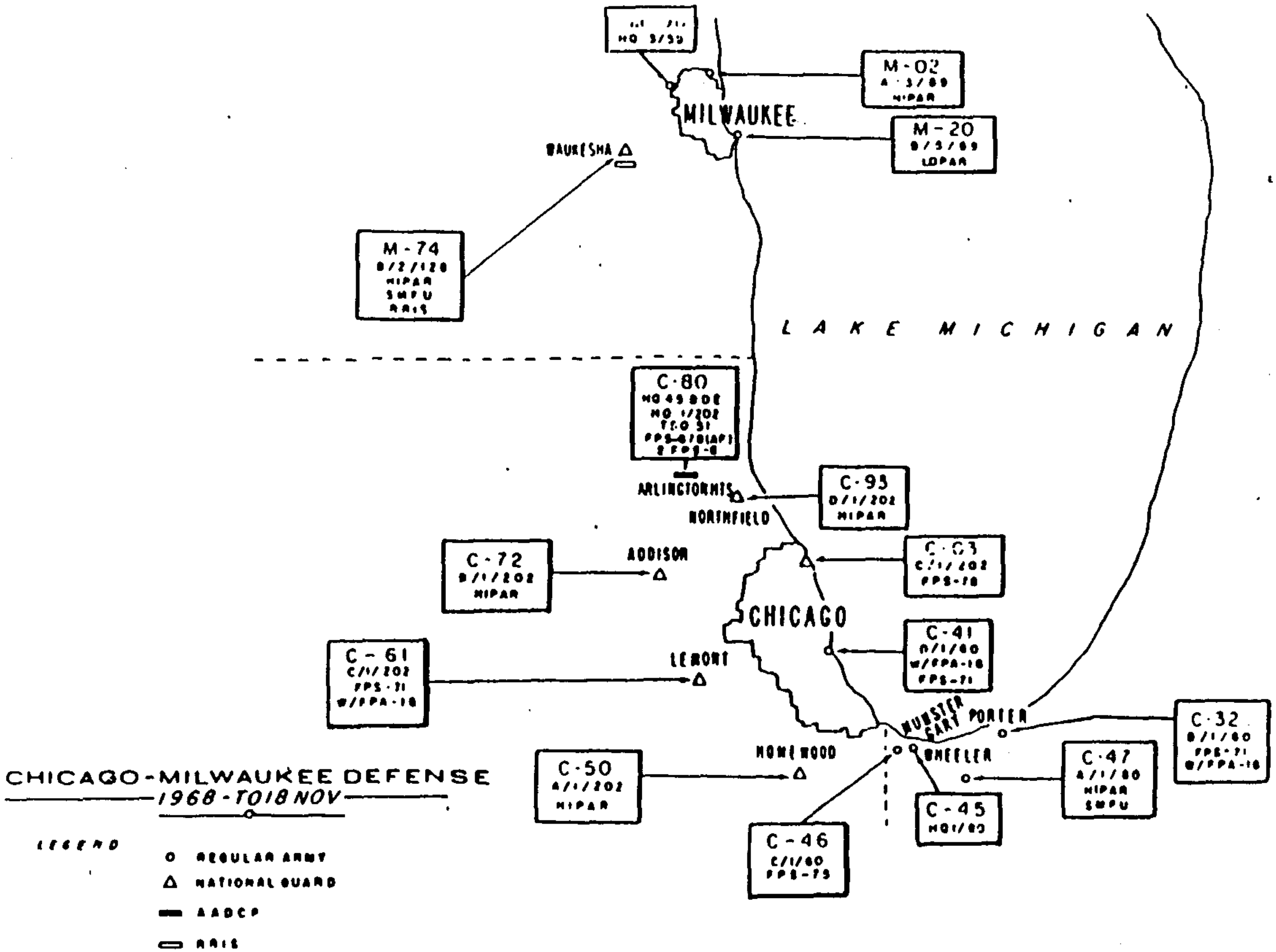
HOMESTEAD-MIAMI DEFENSE
1968



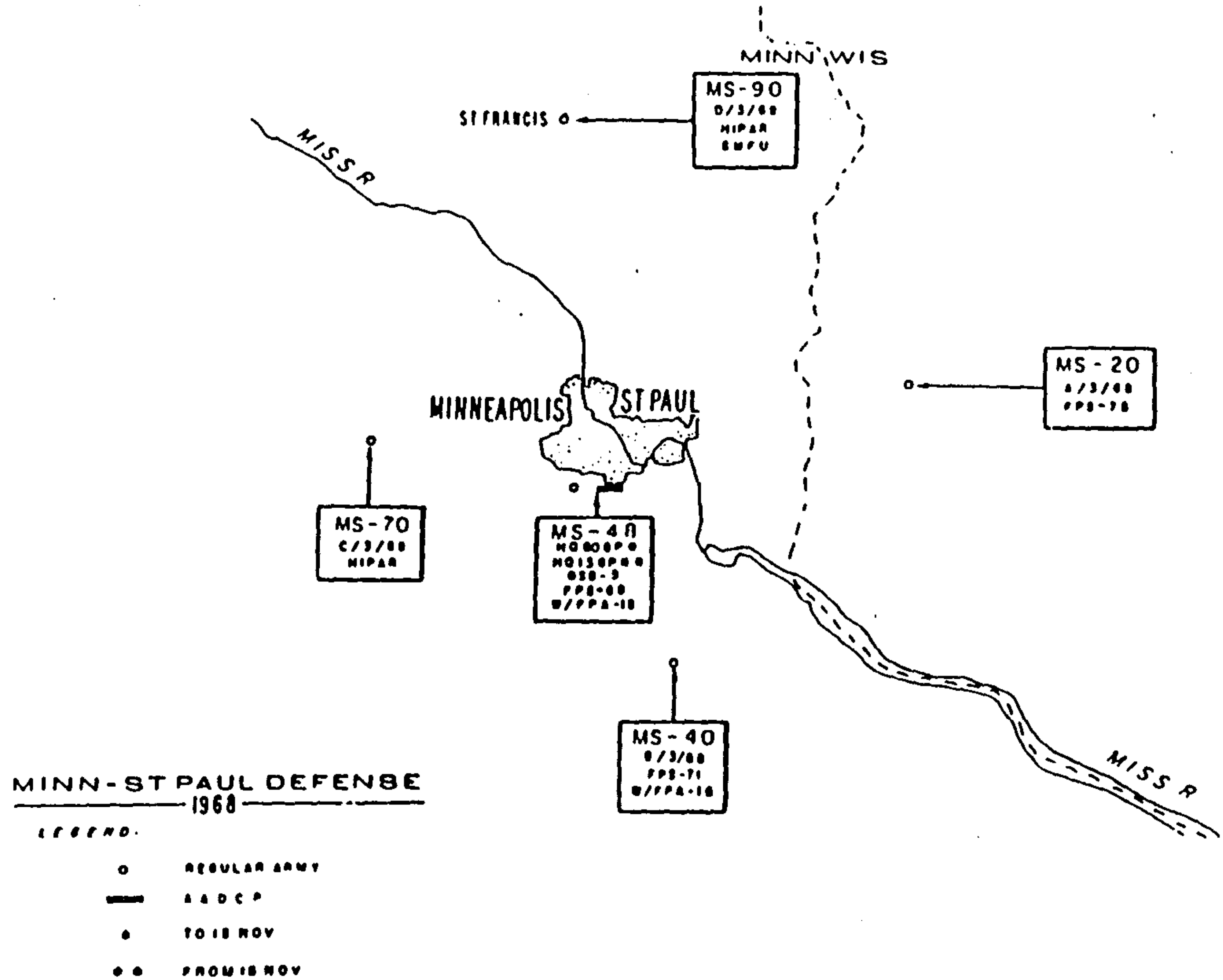
LOS ANGELES DEFENSE
1968-TO NOV

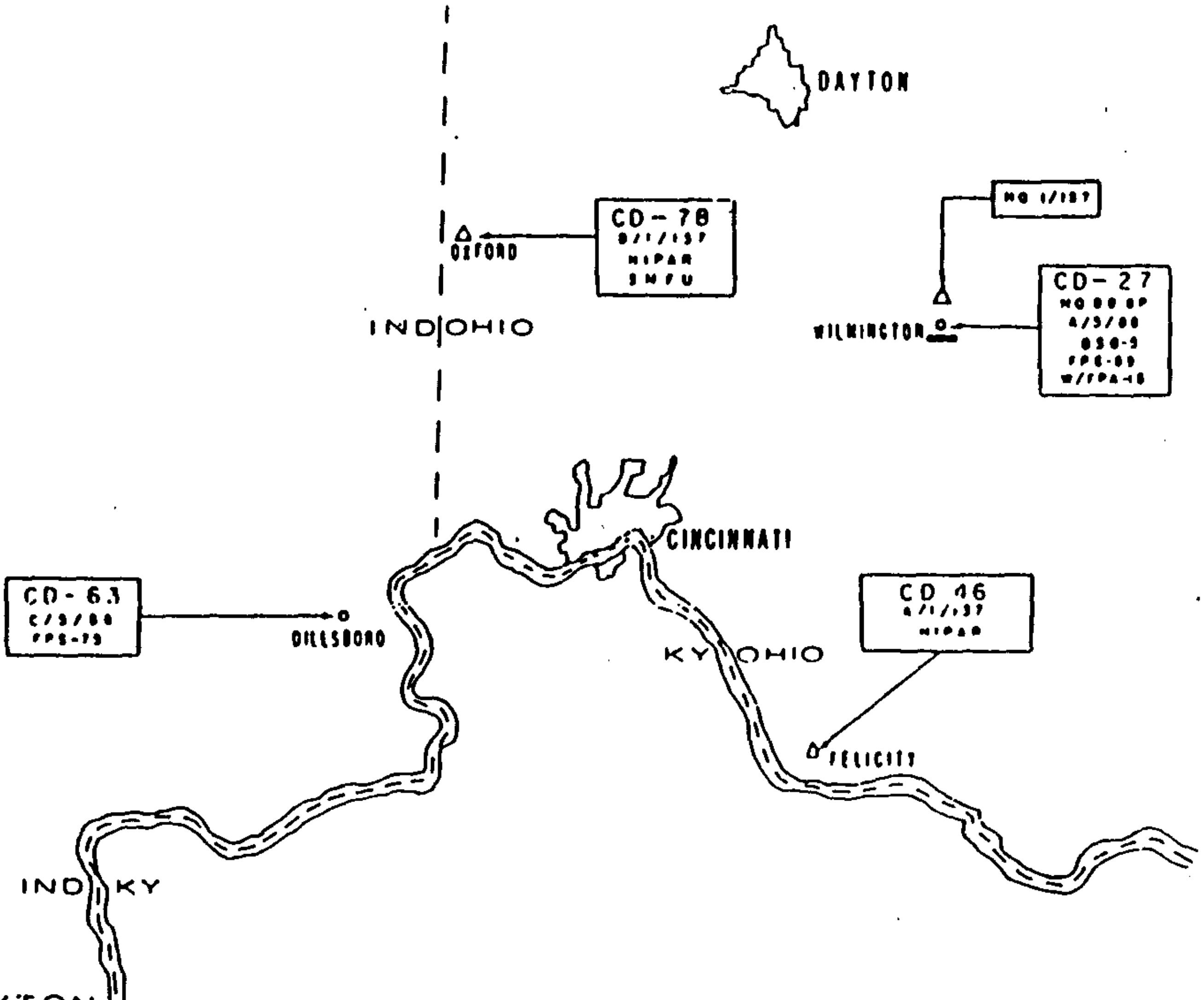
LEGEND:
- o REGULAR ARMY
- Δ NATIONAL GUARD
- AADCP
- ARIS


M 96
M-02
HIPAR
MILWAUKEE
M-20
LOPAR
WAUKESHA
M-74
HIPAR
LAKE MICHIGAN
C-80
ARLINGTON HTS
NORTHFIELD
C-93
D/1/202
HIPAR
C-72
HIPAR
ADDISON
C-C3
CHICAGO
C-41
MUNSTER
PORTER
C-32
WHEELER
C-47
HOMEWOOD
C-50
A/1/202
HIPAR
C-46
CHICAGO-MILWAUKEE DEFENSE
1968-FROM 30 NOV
LEGEND
REGULAR ARMY
NATIONAL GUARD
AADCP



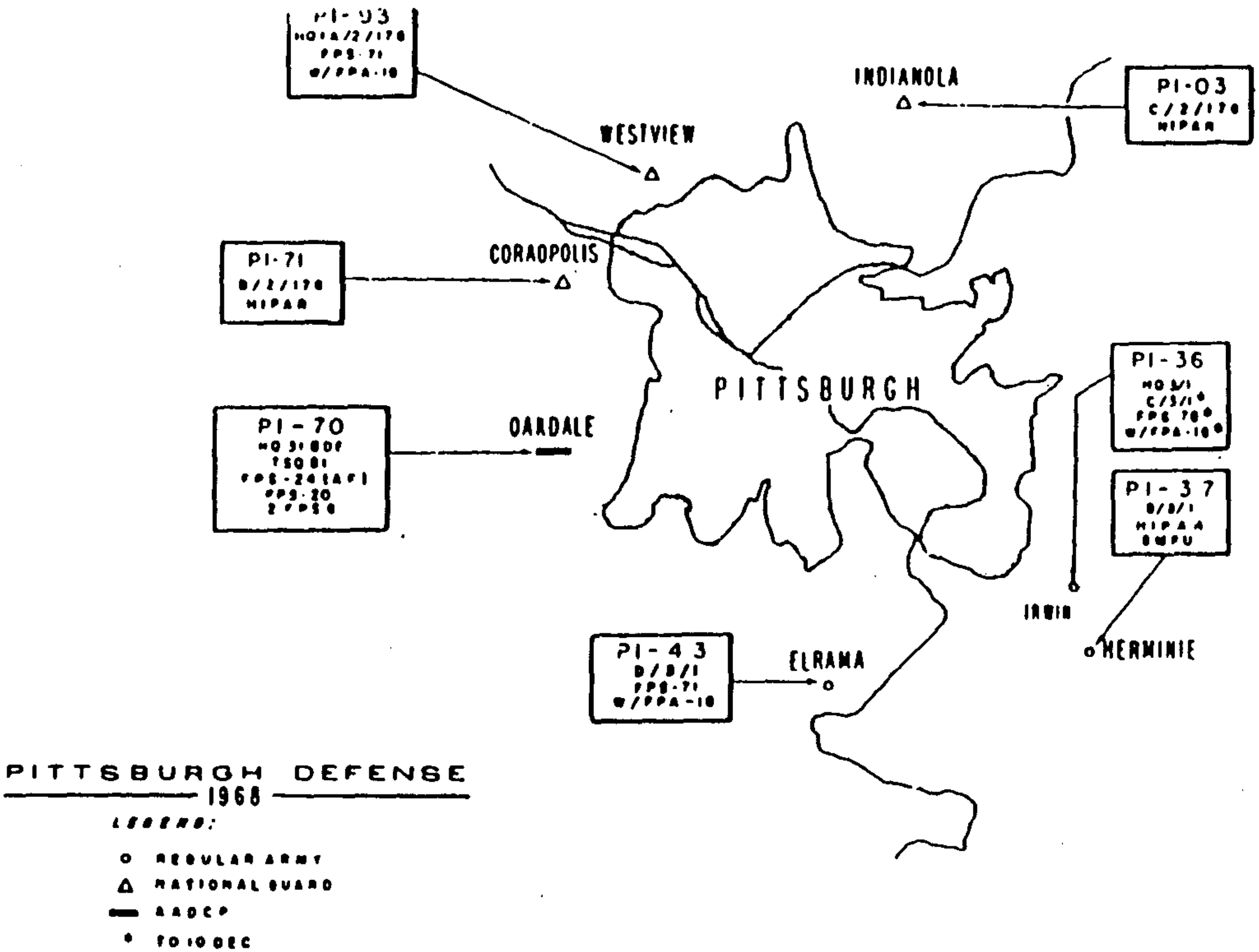
HQ 3/59
M-02
A/3/59
HIPAR
MILWAUKEE
M-20
B/3/59
LOPAR
WAUKESHA
M-74
B/2/128
HIPAR
SMFU
RRIS
LAKE MICHIGAN
C-80
HQ 45 BDE
HQ 1/202
TSQ 51
FPS-6
ARLINGTON HTS
NORTHFIELD
C-93
D/1/202
HIPAR
ADDISON
C-72
B/1/202
HIPAR
C-03
FPS-78
CHICAGO
C-41
D/1/60
W/FPA-16
FPS-71
C-61
C/1/202
FPS-71
W/FPA-16
LEMONT
MUNSTER
GARY
PORTER
C-32
B/1/60
FPS-71
W/FPA-16
HOMEWOOD
WHEELER
C-50
A/1/202
HIPAR
C-47
A/1/60
HIPAR
SMFU
C-45
HQ1/60
C-46
C/1/60
FPS-75
CHICAGO-MILWAUKEE DEFENSE
1968-TO 18 NOV
LEGEND
REGULAR ARMY
NATIONAL GUARD
AADCP
RRIS


MINN WIS
MS-90
ST FRANCIS
MISS R
MS-20
MINNEAPOLIS
ST PAUL
MS-70
MS-40
MS-40
MISS R
MINN-ST PAUL DEFENSE
1968

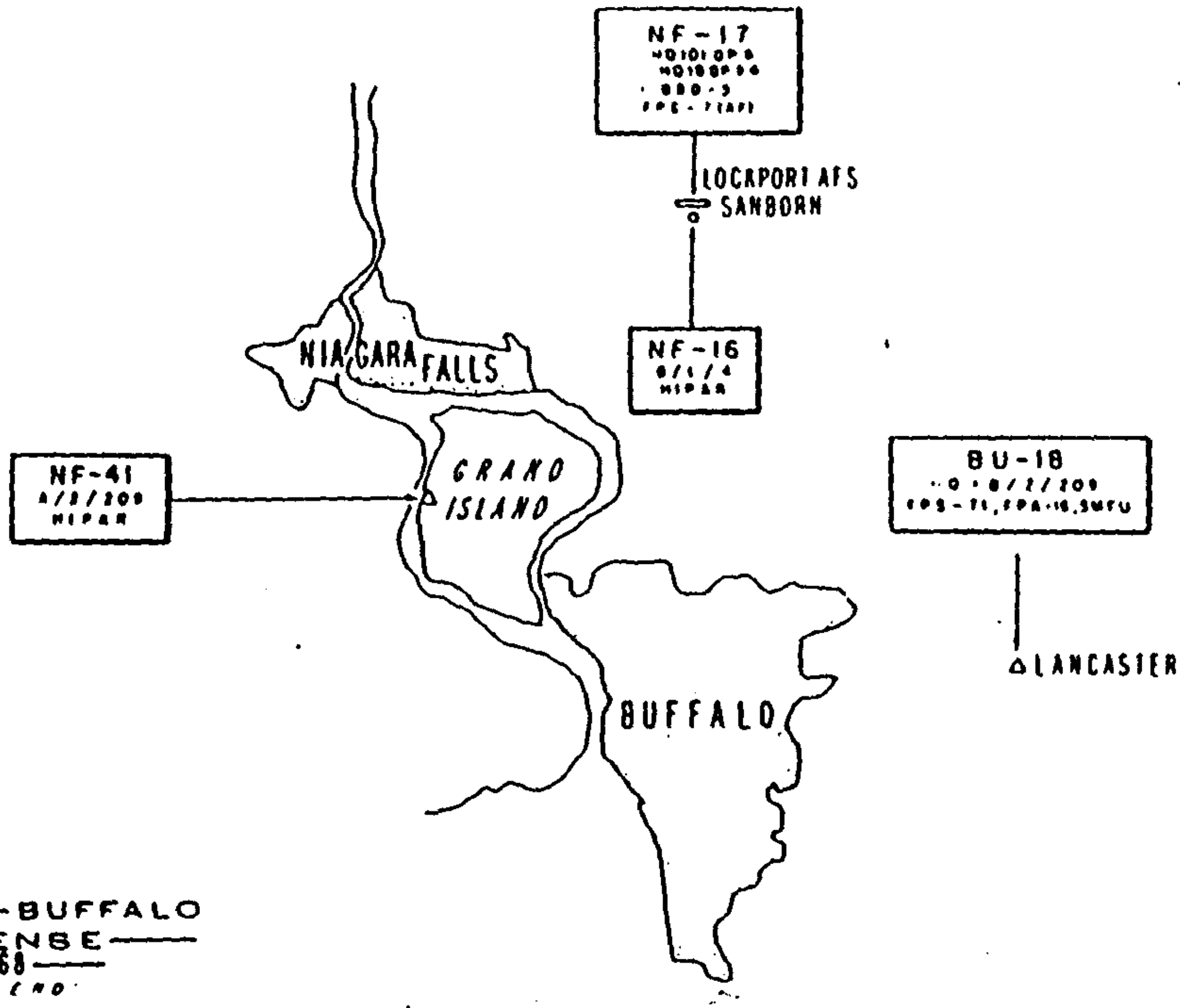


CINCINNATI-DAYTON
DEFENSE
1968

LEGEND
o REGULAR ARMY
Δ NATIONAL GUARD
AADCP



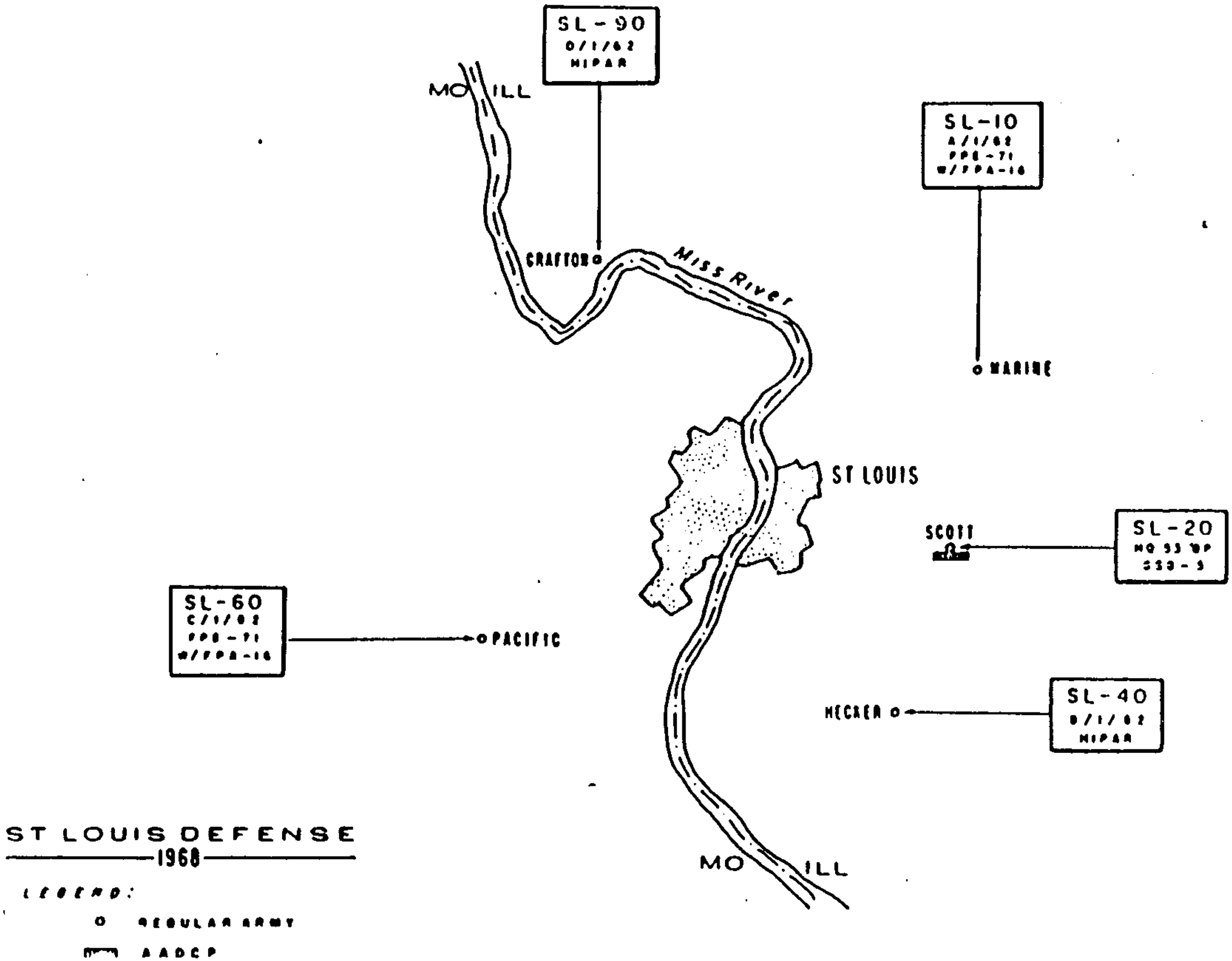
PI-93
PI-03
INDIANOLA
WESTVIEW
PI-71
CORAOPOLIS
PITTSBURGH
PI-70
OAKDALE
PI-36
PI-37
IRWIN
HERMINIE
PI-43
ELRAMA
PITTSBURGH DEFENSE
1968
LEGEND:
REGULAR ARMY
NATIONAL GUARD
AADCP
TO 10 DEC

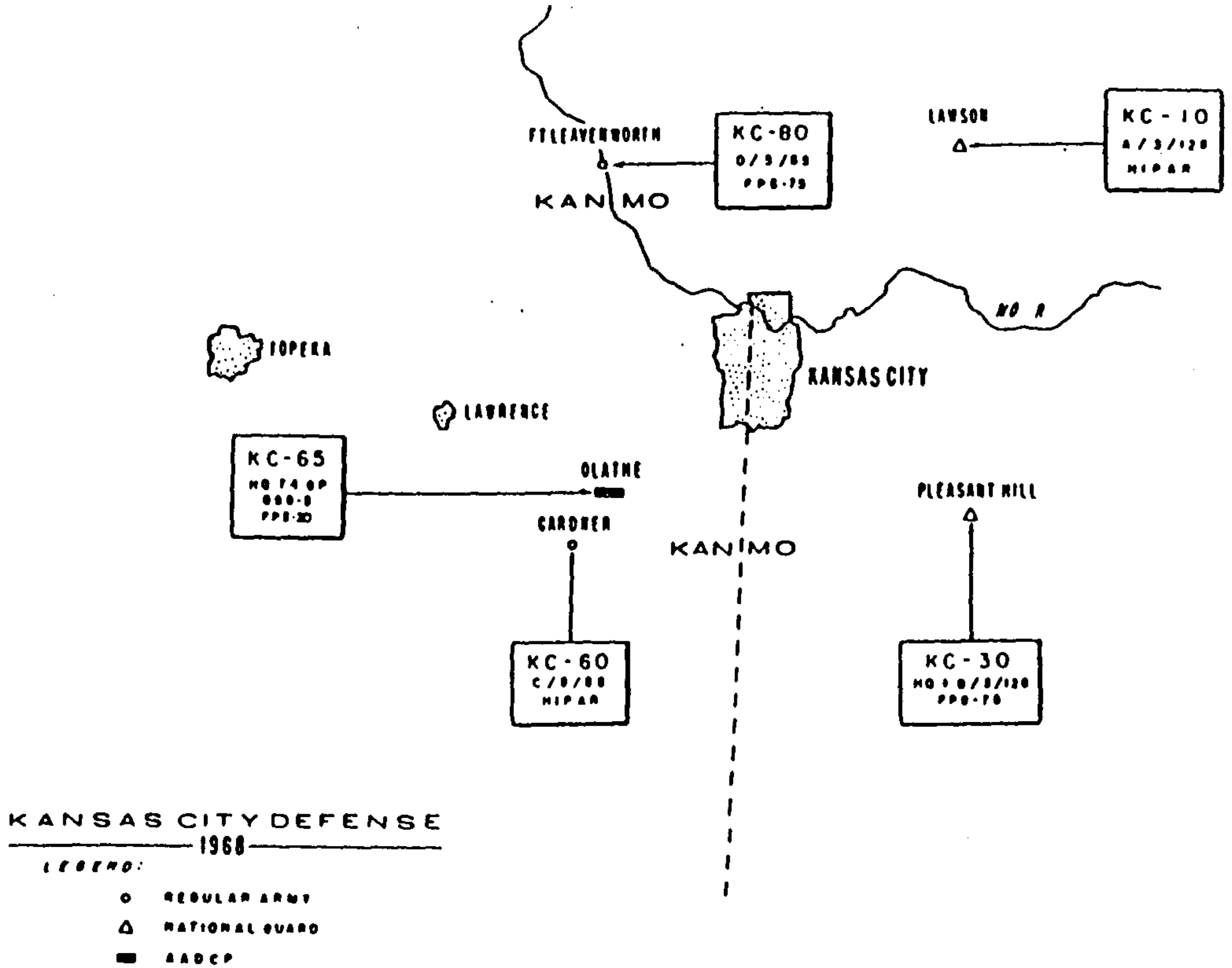


NIAGARA-BUFFALO
DEFENSE
1968

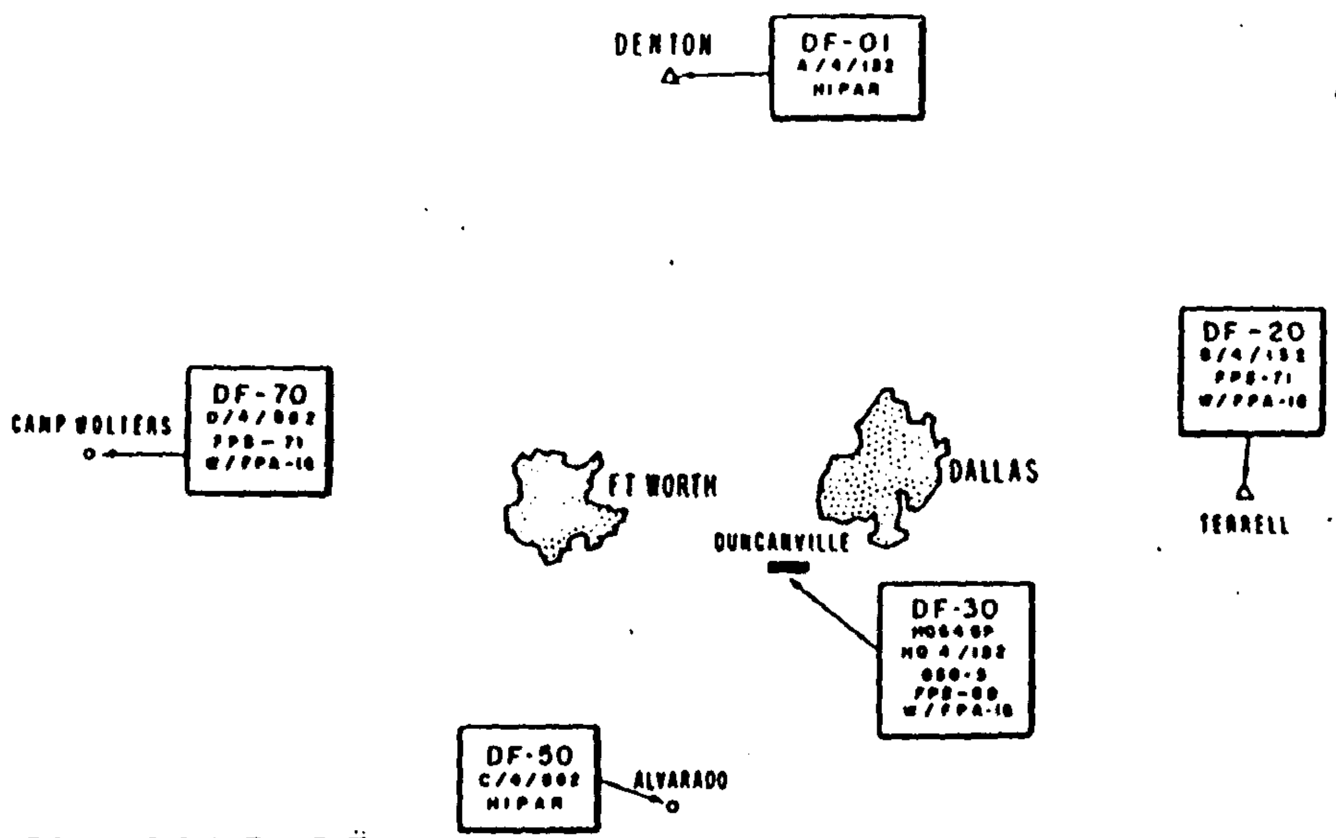
LEGEND

- ○ REGULAR ARMY
- △ NATIONAL GUARD
- AADCP
- • TO 15 NOV
- •• FROM 15 NOV


SL-90
D/1/62
HIPAR
MO
ILL
GRAFTON
Miss River
SL-10
A/1/62
MARINE
ST LOUIS
SCOTT
SL-20
SL-60
C/1/62
W/FPA-16
PACIFIC
HECKER
SL-40
B/1/62
HIPAR
MO
ILL
ST LOUIS DEFENSE
1968
LEGEND:
REGULAR ARMY
AADCP



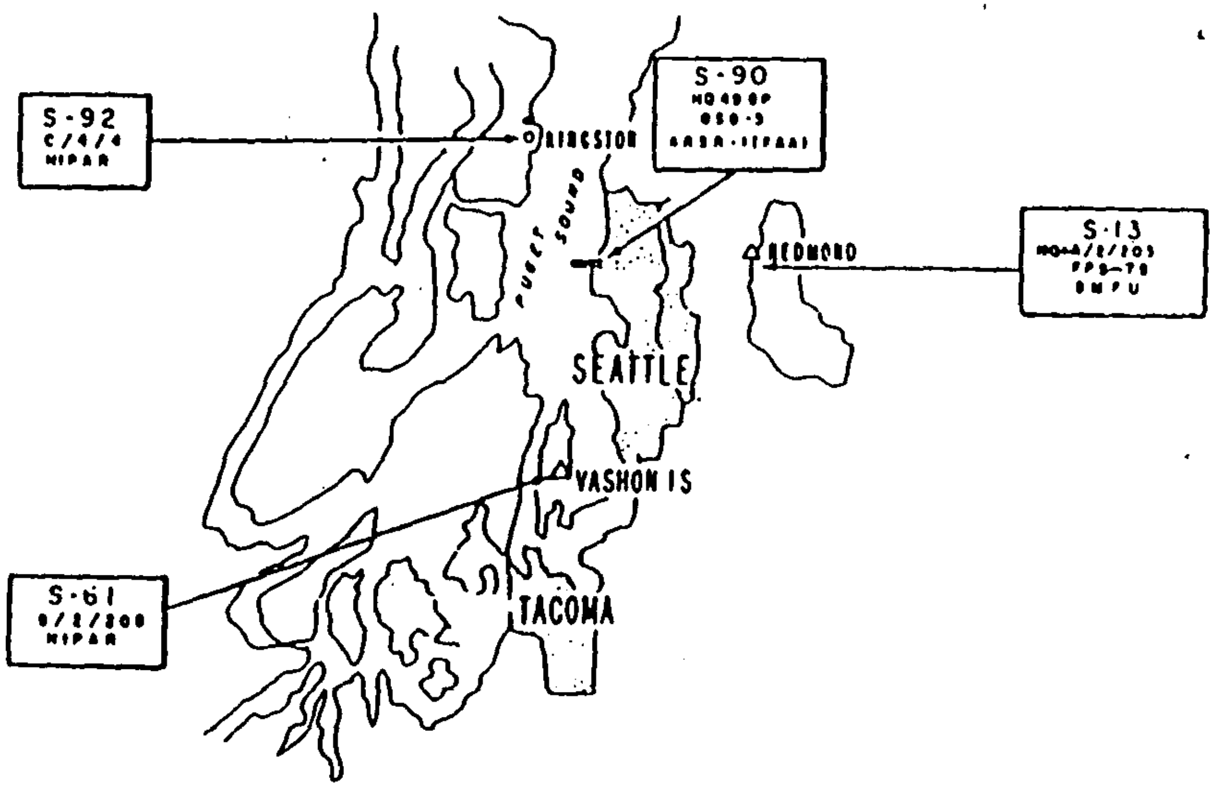
KANSAS CITY DEFENSE
1968



DALLAS-FT WORTH DEFENSE
1968

LEGEND

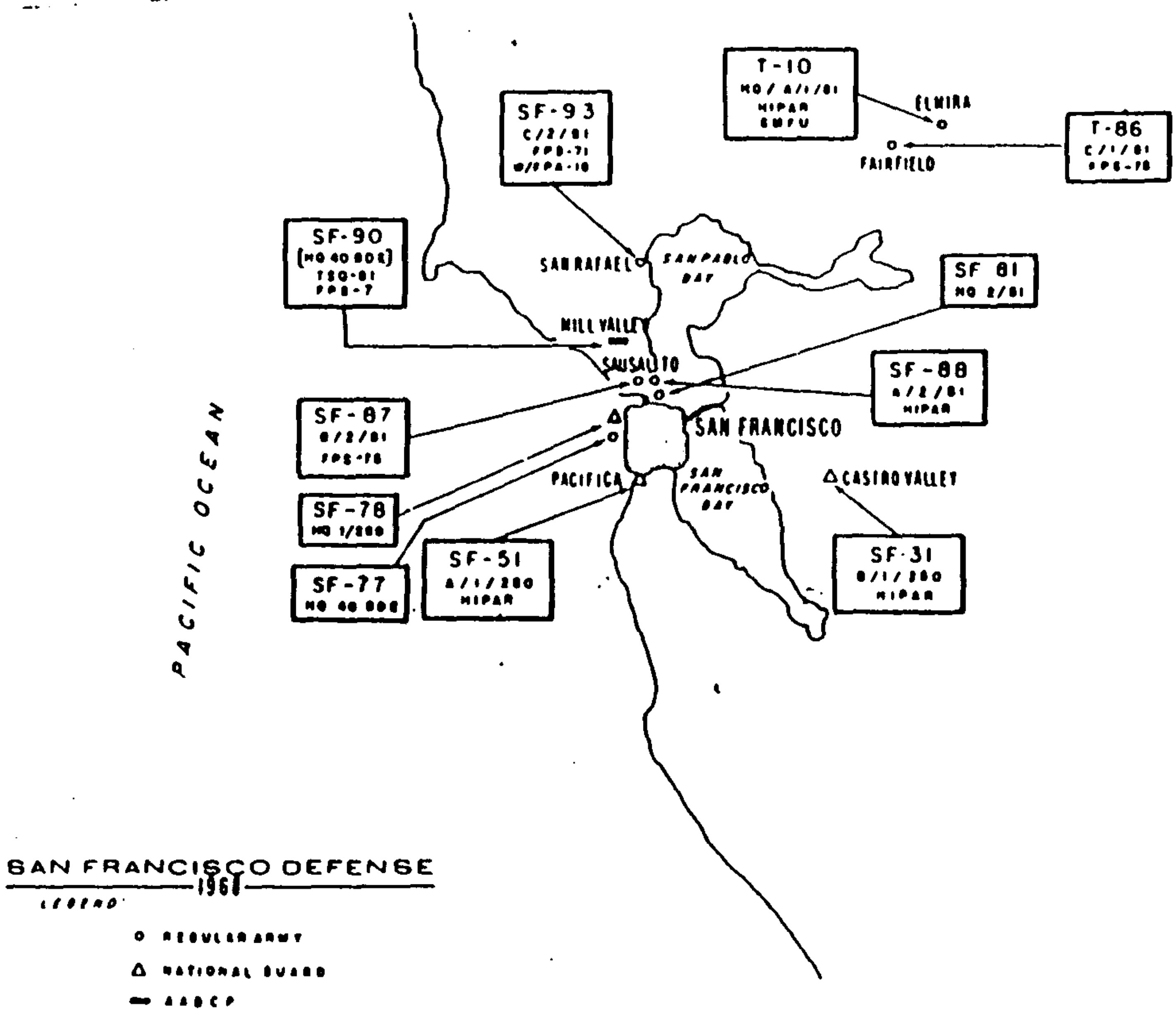
○ REGULAR ARMY
△ NATIONAL GUARD
▬ AADCP

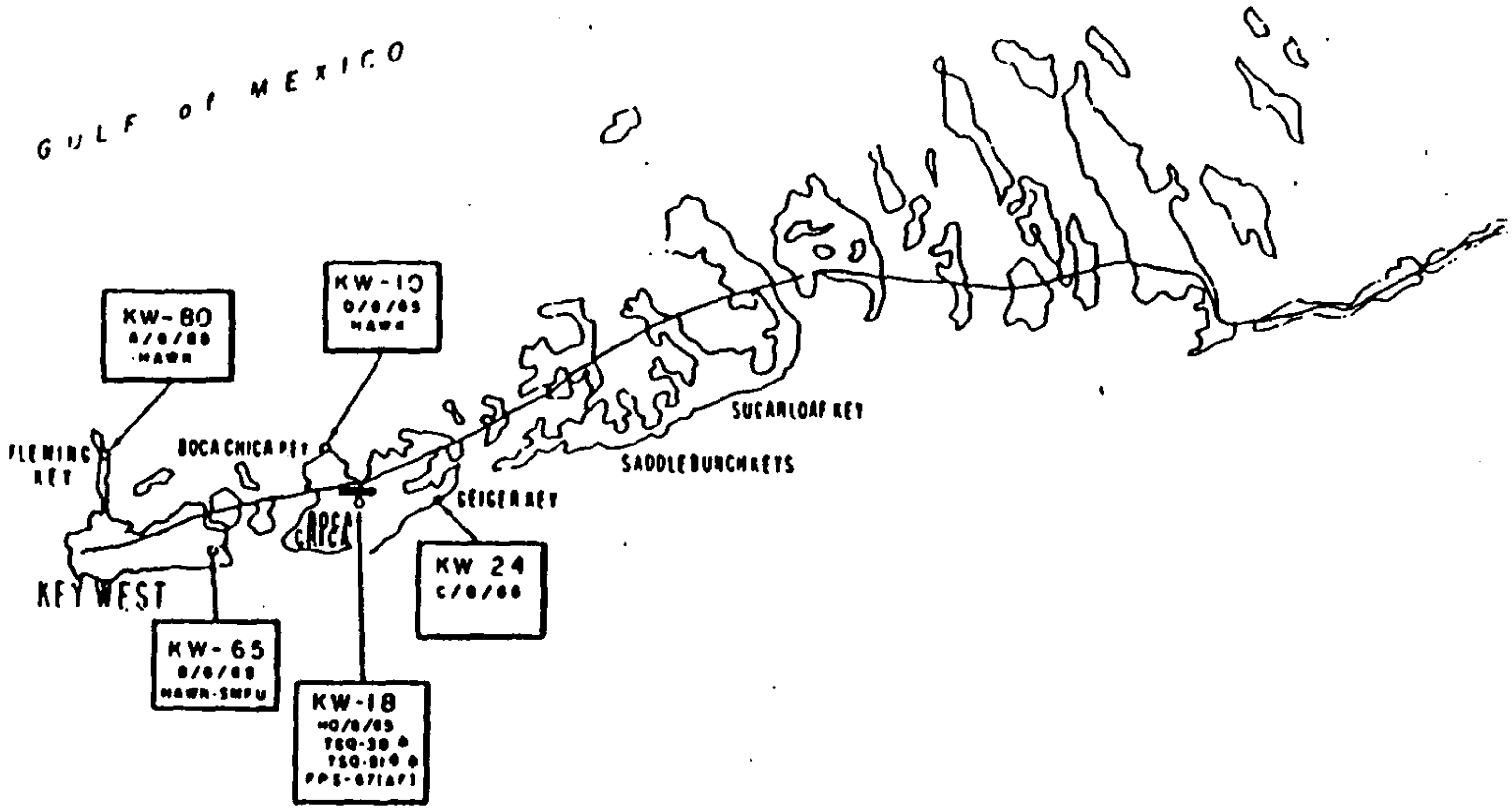


SEATTLE DEFENSE
1968

LEGEND:

- ○ REGULAR ARMY
- △ NATIONAL GUARD
- ▬ AADCP

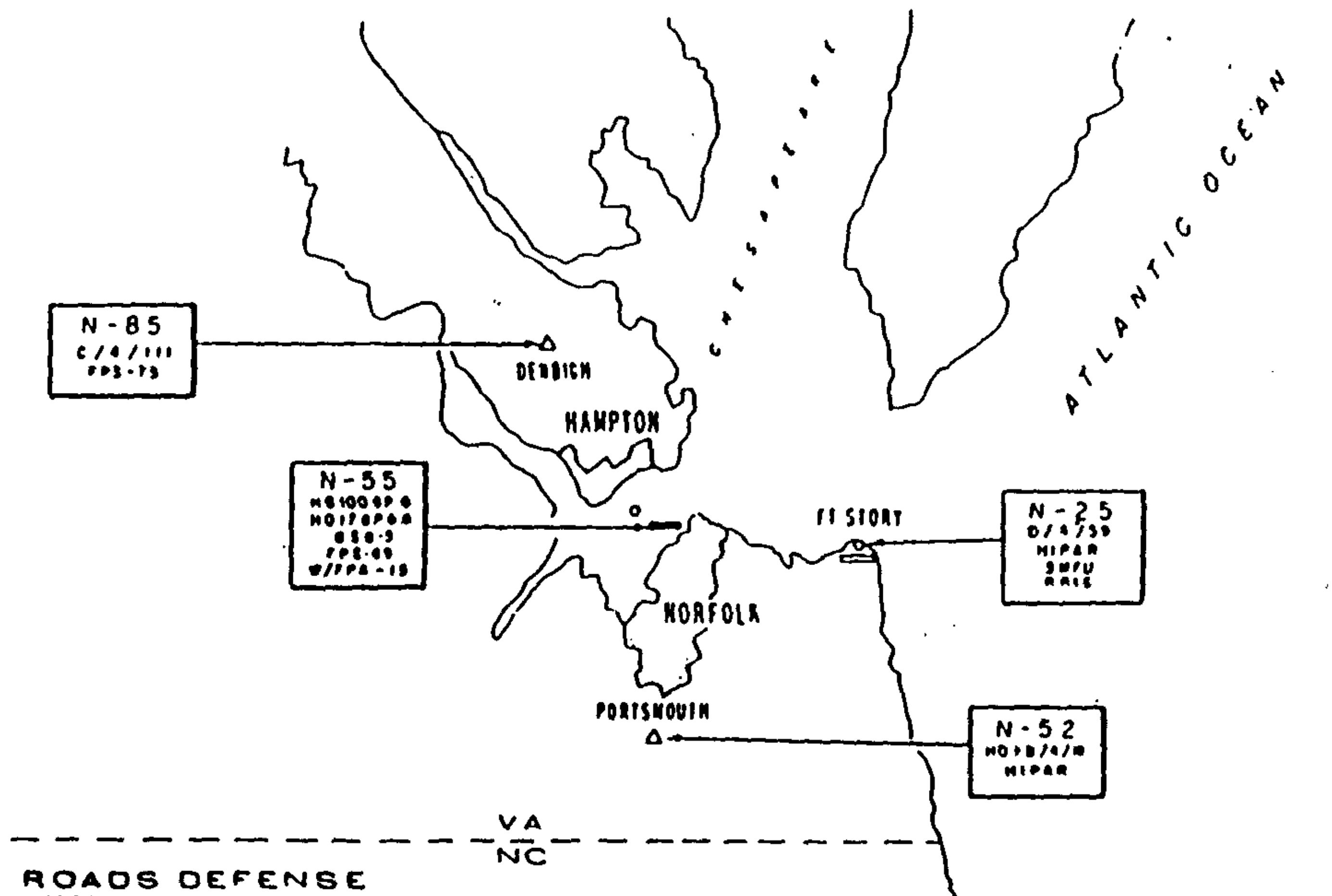

SAN FRANCISCO DEFENSE
LEGEND
REGULAR ARMY
NATIONAL GUARD
AADCP
PACIFIC OCEAN
SAN FRANCISCO
SAN FRANCISCO BAY
SAN PABLO BAY
SAN RAFAEL
MILL VALLEY
SAUSALITO
PACIFICA
CASTRO VALLEY
ELMIRA
FAIRFIELD
T-10
T-86
SF-93
SF-90
SF 81
SF-88
SF-87
SF-78
SF-77
SF-51
SF-31
HIPAR



KEY WEST DEFENSE
1968

LEGEND:

- REGULAR ARMY
- AADCP
- TO 1 WAY (MANUAL OPNS TO 1 OCT)
- FROM 1 OCT

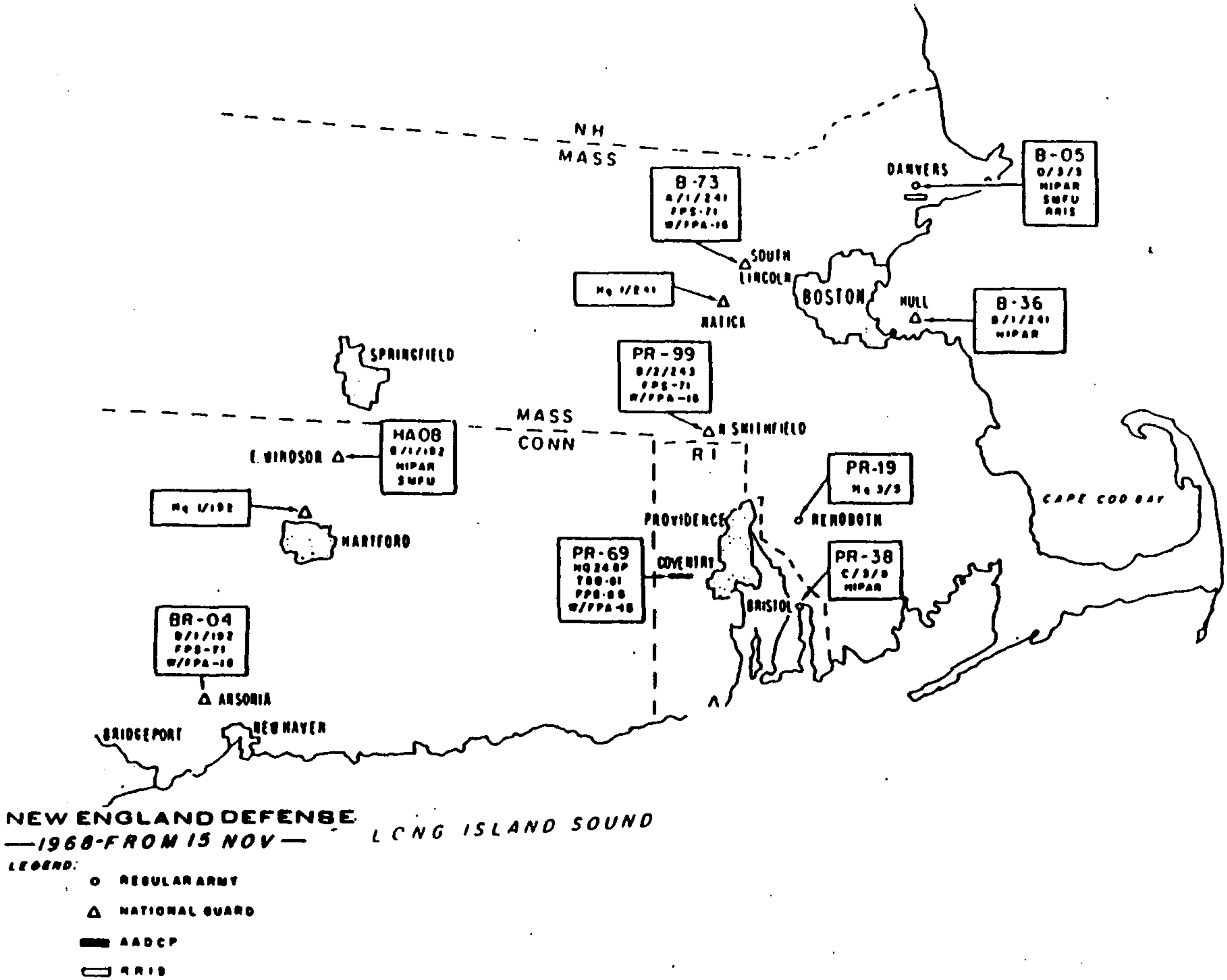


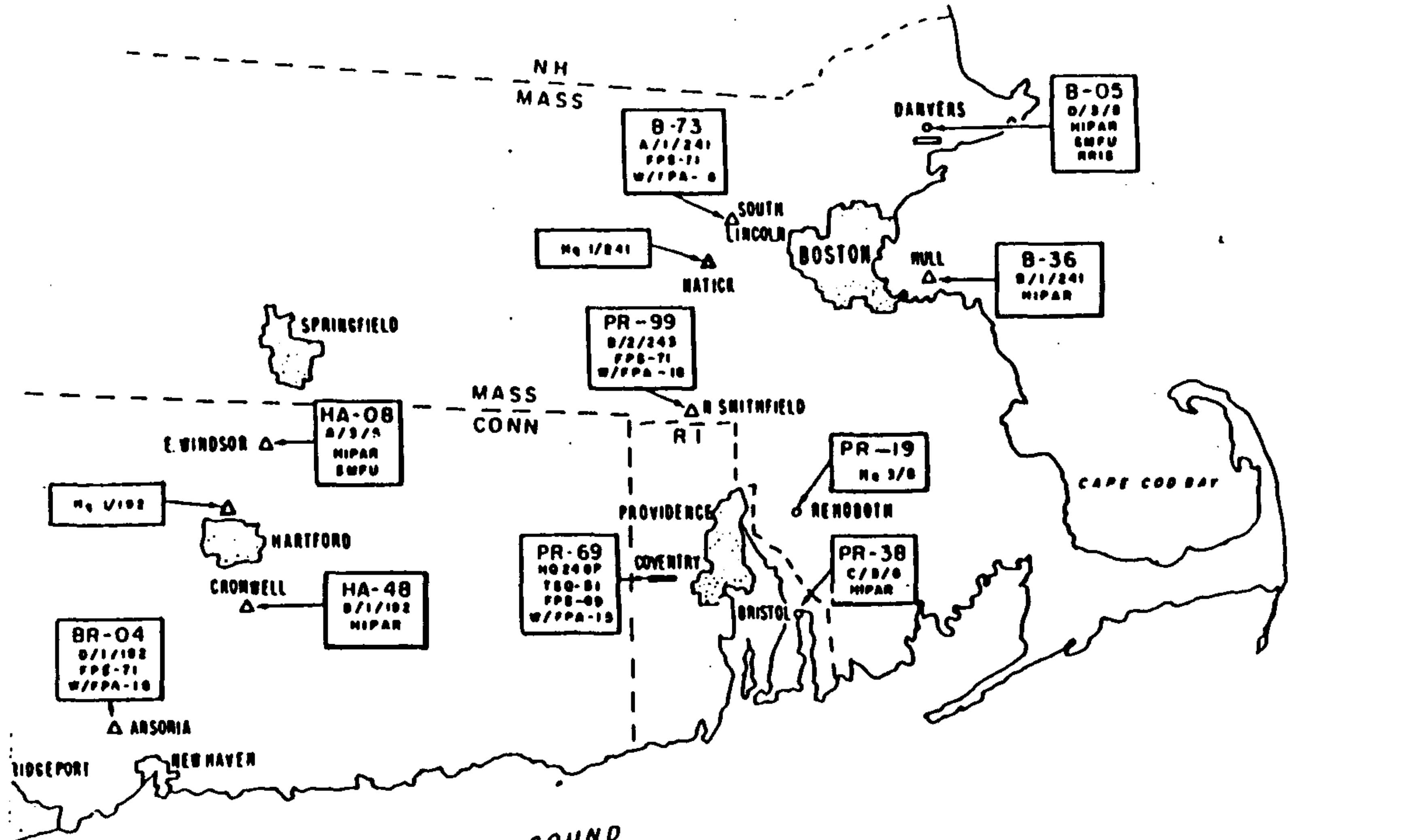
HAMPTON ROADS DEFENSE

1968

LEGEND:

- o REGULAR ARMY
- Δ NATIONAL GUARD
- AADCP
- RRIE (PART of WASH/BALT DEF)
- TO 15 NOV
- FROM 15 NOV

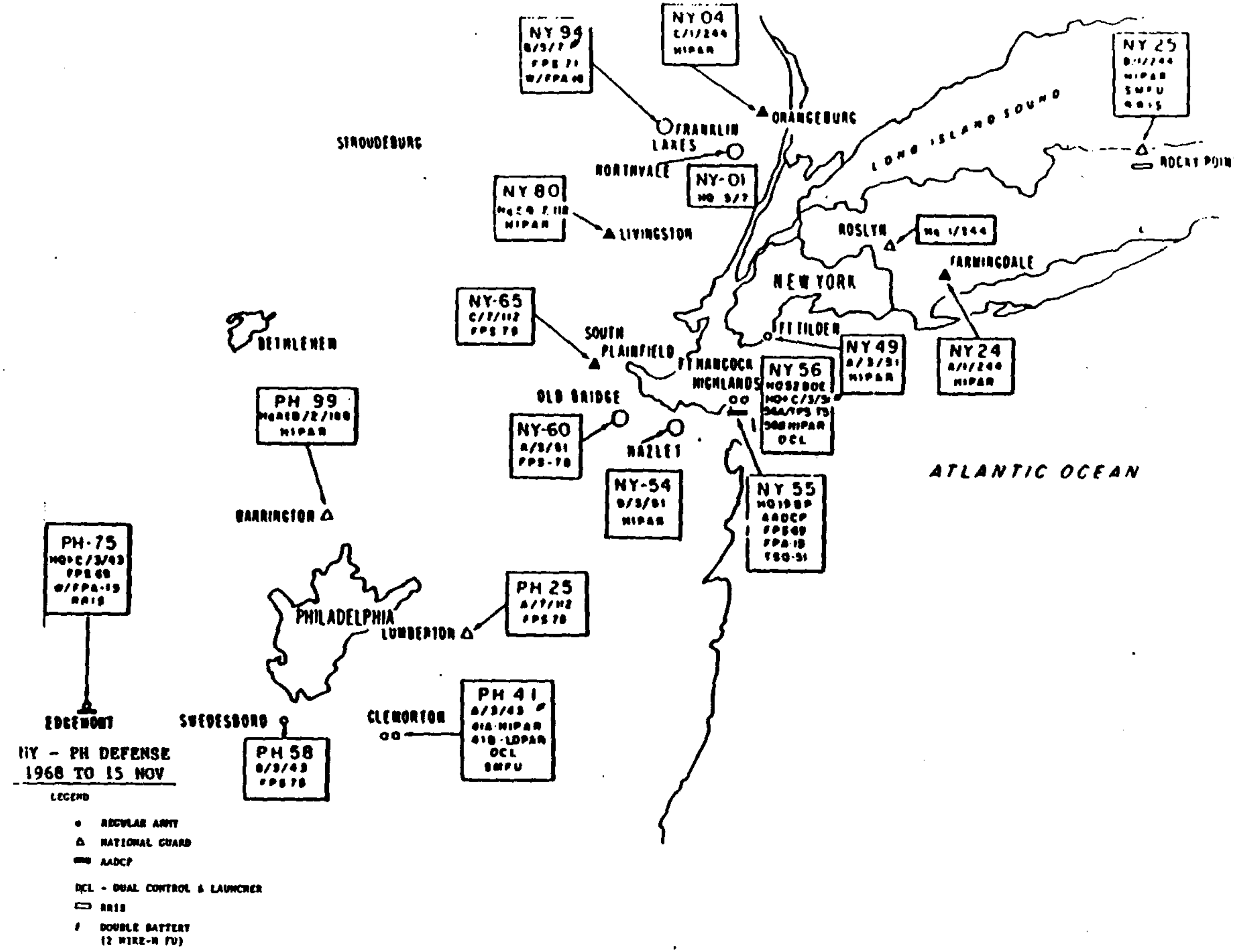

NH
MASS
B-73
SOUTH LINCOLN
DANVERS
B-05
HIPAR
BOSTON
NATICK
HULL
B-36
HIPAR
SPRINGFIELD
PR-99
N SMITHFIELD
MASS
CONN
R I
HA08
E. WINDSOR
HIPAR
HARTFORD
PR-19
REHOBOTH
PROVIDENCE
PR-69
COVENTRY
PR-38
HIPAR
BRISTOL
CAPE COD BAY
BR-04
ANSONIA
BRIDGEPORT
NEW HAVEN
LONG ISLAND SOUND
NEW ENGLAND DEFENSE
—1968-FROM 15 NOV—
LEGEND:
REGULAR ARMY
NATIONAL GUARD
AADCP



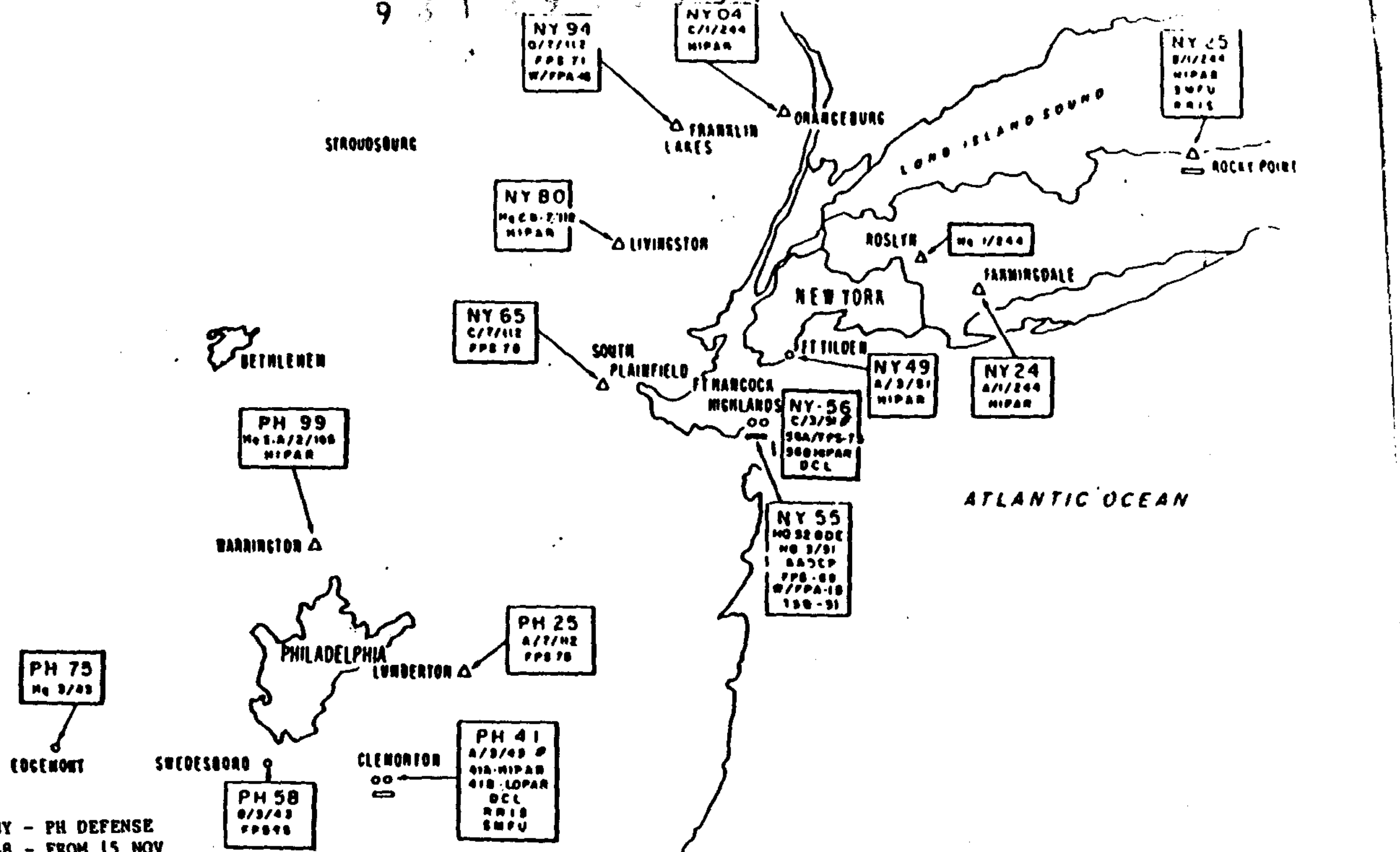
NEW ENGLAND DEFENSE
—— 1968-TO 15 NOV ——

LEGEND:

- o REGULAR ARMY
- Δ NATIONAL GUARD
- AADCP
- RRIS



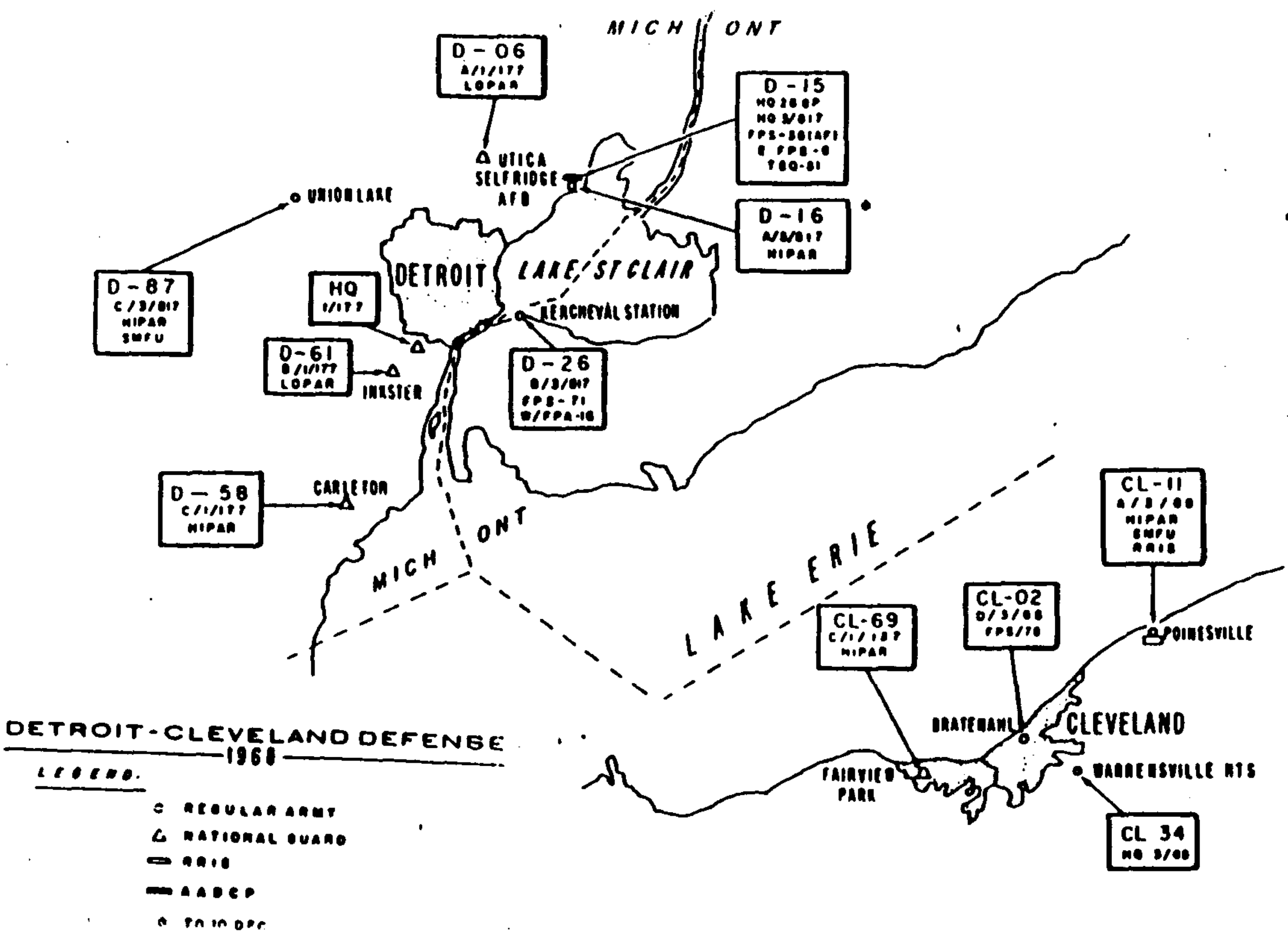
NY 94
NY 04
HIPAR
ORANGEBURG
FRANKLIN LAKES
NORTHVALE
NY-01
NY 25
ROCKY POINT
LONG ISLAND SOUND
STROUDSBURG
NY 80
HIPAR
LIVINGSTON
ROSLYN
FARMINGDALE
NEW YORK
NY-65
SOUTH PLAINFIELD
BETHLEHEM
FT TILDEN
NY 49
HIPAR
NY 24
HIPAR
FT HANCOCK HIGHLANDS
NY 56
HIPAR
DCL
PH 99
HIPAR
OLD BRIDGE
NY-60
HAZLET
NY-54
HIPAR
NY 55
AADCP
ATLANTIC OCEAN
HARRINGTON
PH-75
PH 25
PHILADELPHIA
LUMBERTON
PH 41
DCL
CLEMORTON
EDGEMONT
SWEDESBORO
PH 58
NY - PH DEFENSE
1968 TO 15 NOV
LEGEND
REGULAR ARMY
NATIONAL GUARD
AADCP
DCL - DUAL CONTROL & LAUNCHER
RRIS
DOUBLE BATTERY
(2 NIKE-H FU)



NY - PH DEFENSE
1968 - FROM 15 NOV

LEGEND

- ● REGULAR ARMY
- △ NATIONAL GUARD
- ▬ AADCP
- DCL - DUAL CONTROL & LAUNCHER
- ▭ RRIS
- # DOUBLE BATTERY (2 NIKE-H FU)



DETROIT-CLEVELAND DEFENSE
1960

APPENDIX C

GEOGRAPHIC AREAS OF RESPONSIBILITY FOR ARAACOM, ARADCOM, AND NORAD FOR THE PERIOD 1950 TO 1973

"NOTICE:

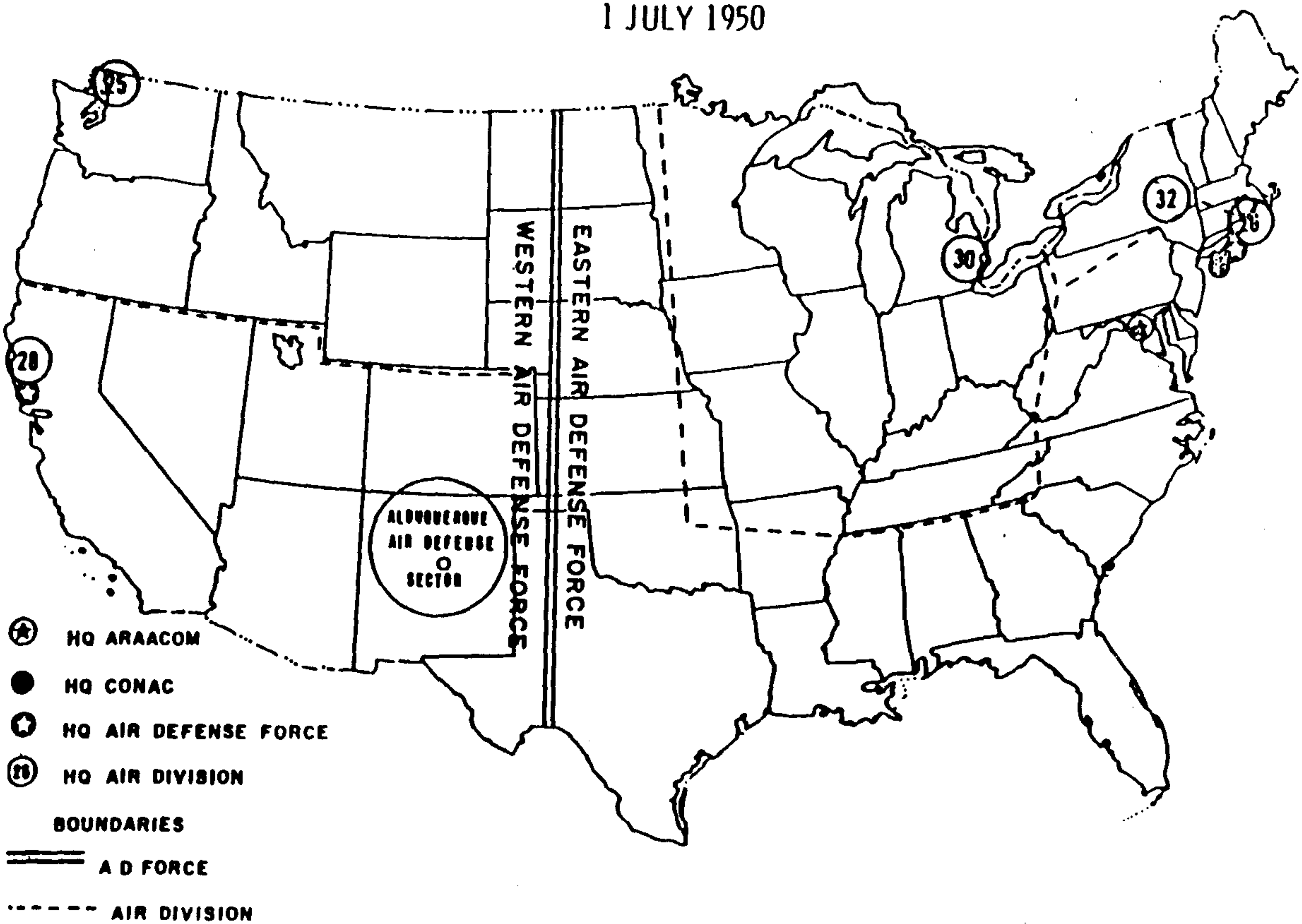
The documents contained in this Appendix have been reproduced from the best copies available. Although certain portions are illegible, this material is being released in the interest of making available as much information as possible.

APPENDIX C

GEOGRAPHIC AREAS OF RESPONSIBILITY FOR ARAACOM, ARADCOM, AND NORAD FOR THE PERIOD 1950 TO 1973

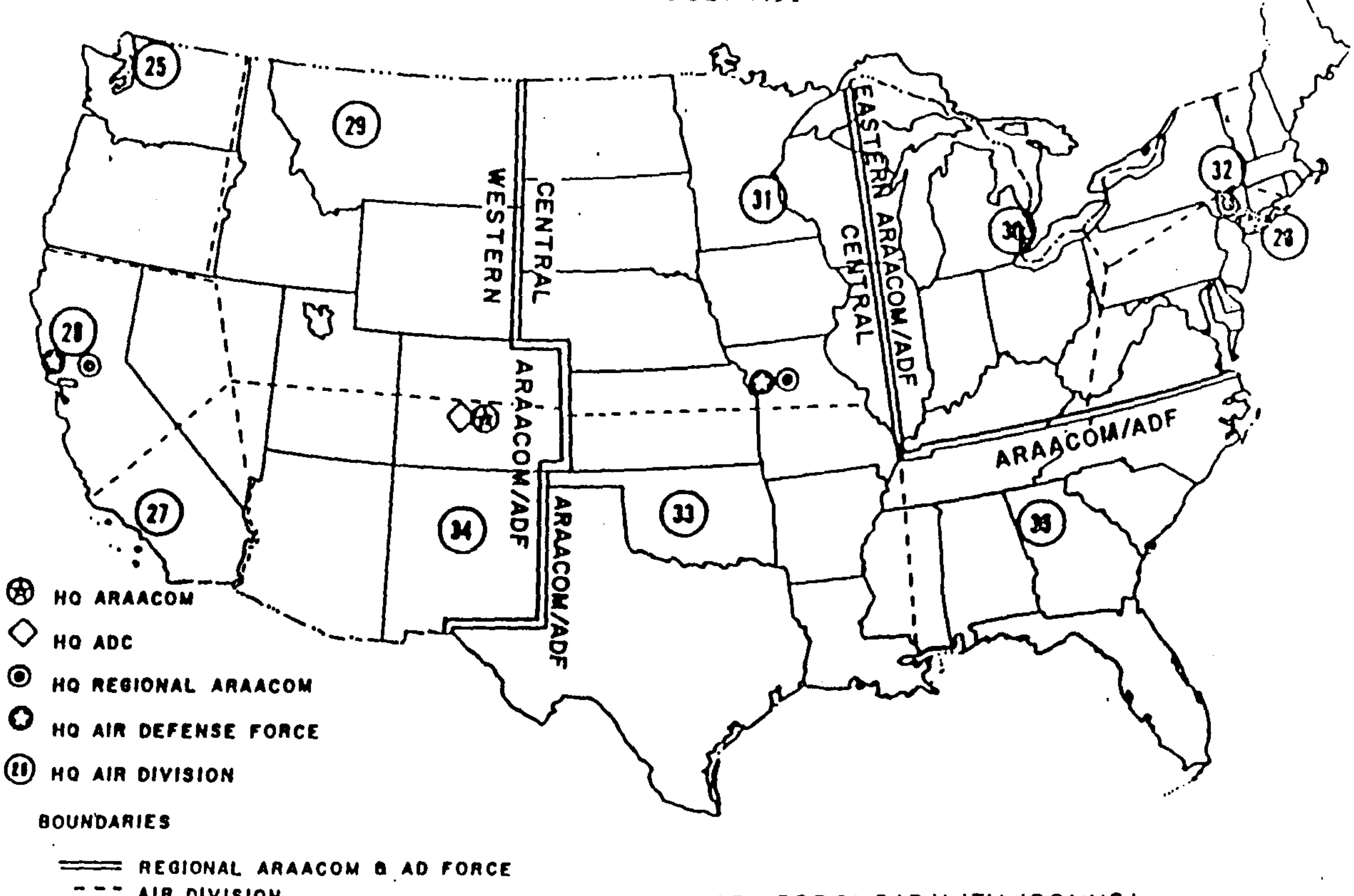
The maps presented in this section show the different administrative regions which existed within ARAACOM during the Nike program. The variation illustrated may be one of the main reasons why no significant regional differences in battery operations were found. Regional boundaries changed so frequently that administrative control of many individual batteries shifted annually. This would necessarily inhibit evolution of "regional" procedures, since no administrative framework remained in place for an extended period.

1 JULY 1950



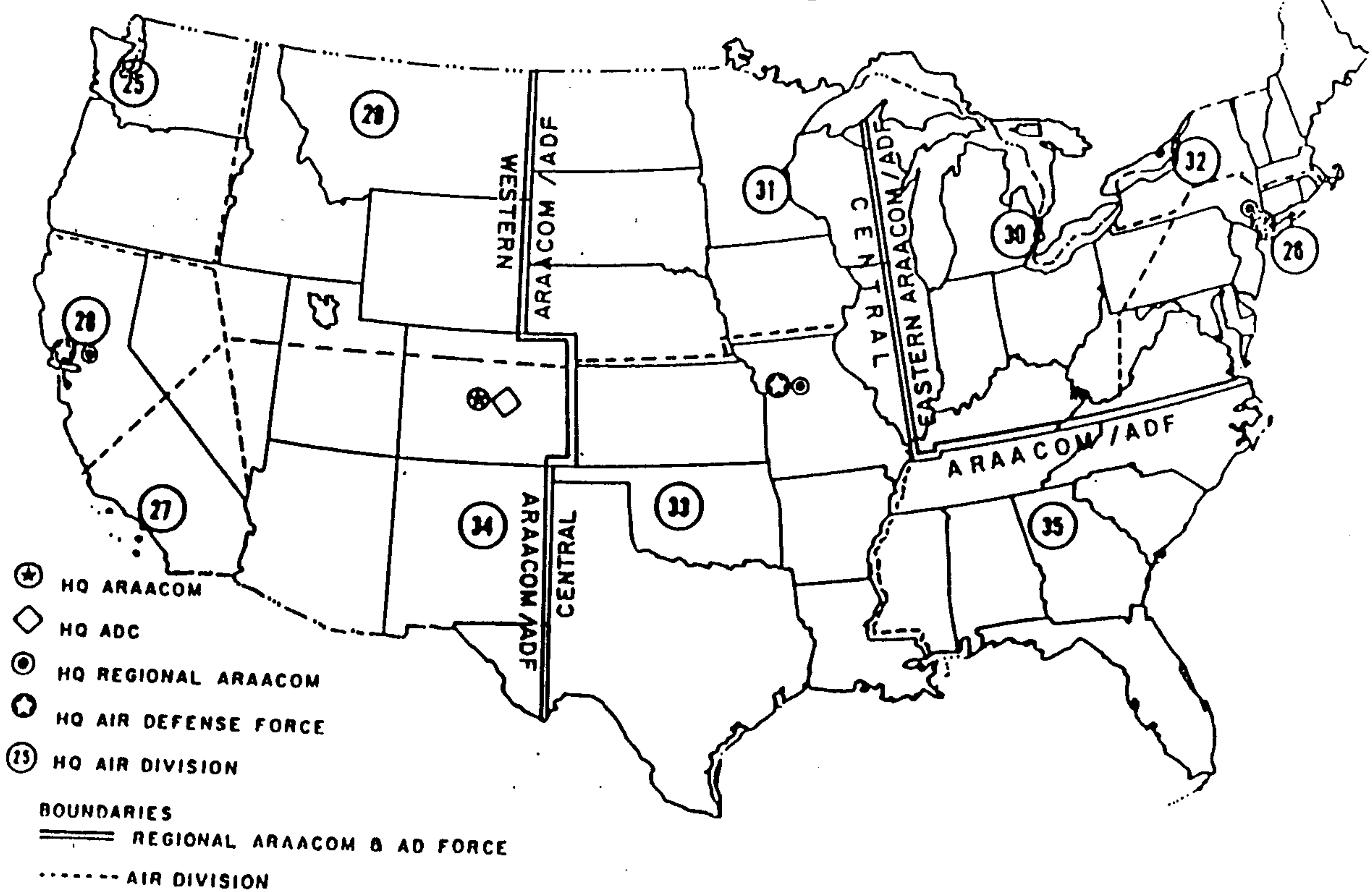
HEADQUARTERS AND AREAS OF RESPONSIBILITY (CONUS)

1 JULY 1951



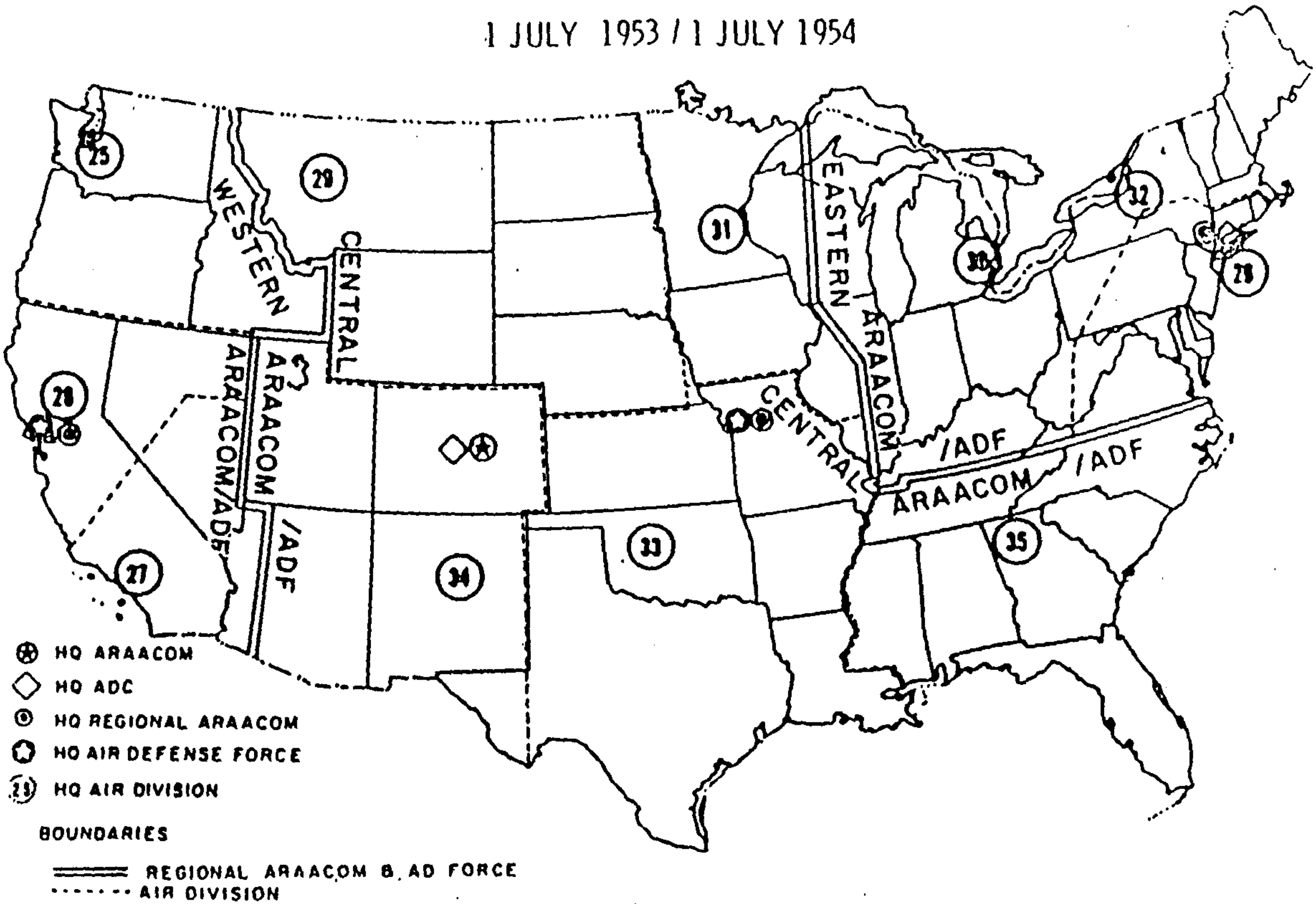
HEADQUARTERS AND AREAS OF RESPONSIBILITY (CONUS)

1 JULY 1952



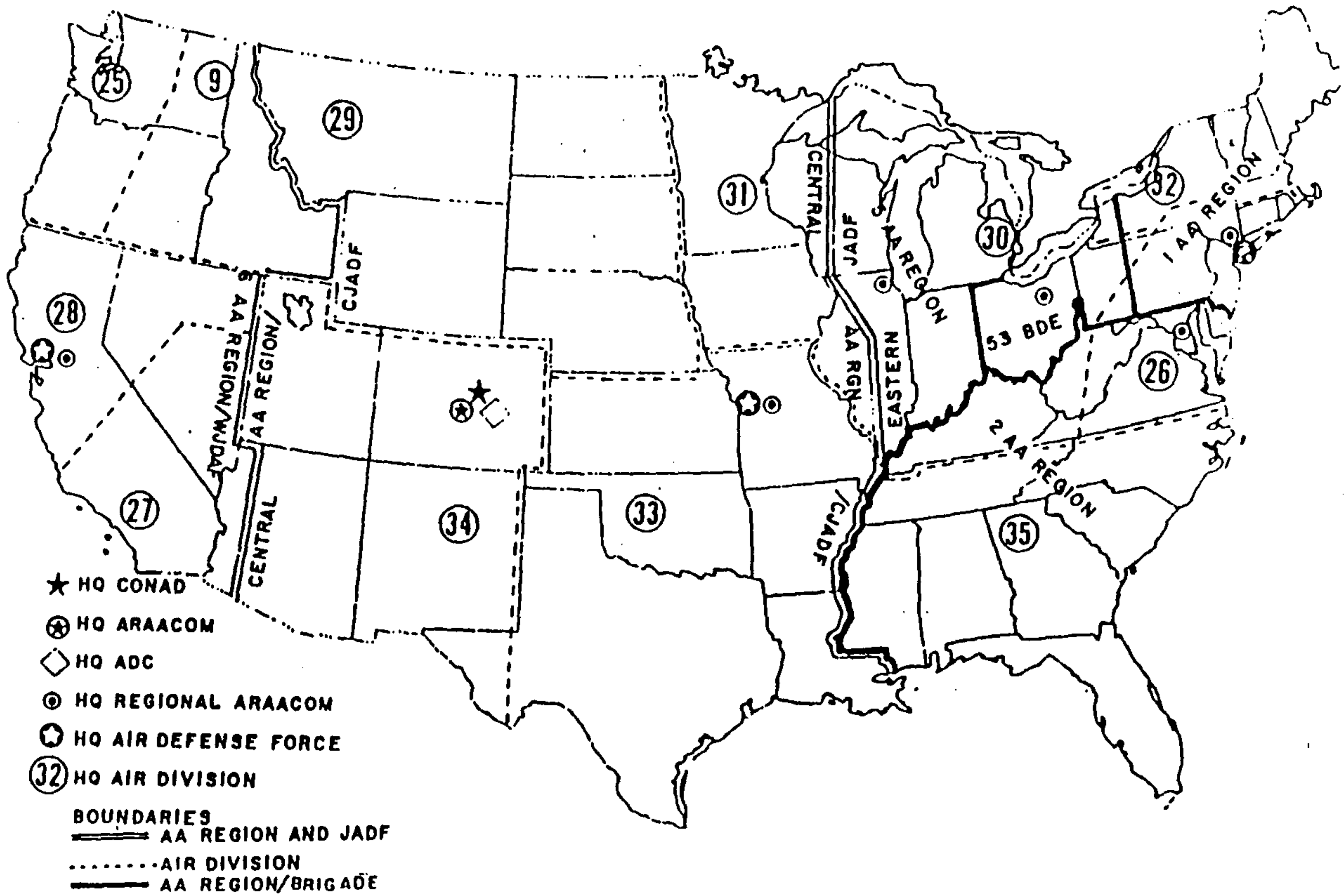
HEADQUARTERS AND AREAS OF RESPONSIBILITY (CONUS)

1 JULY 1953 / 1 JULY 1954



HEADQUARTERS AND AREAS OF RESPONSIBILITY (CONUS)

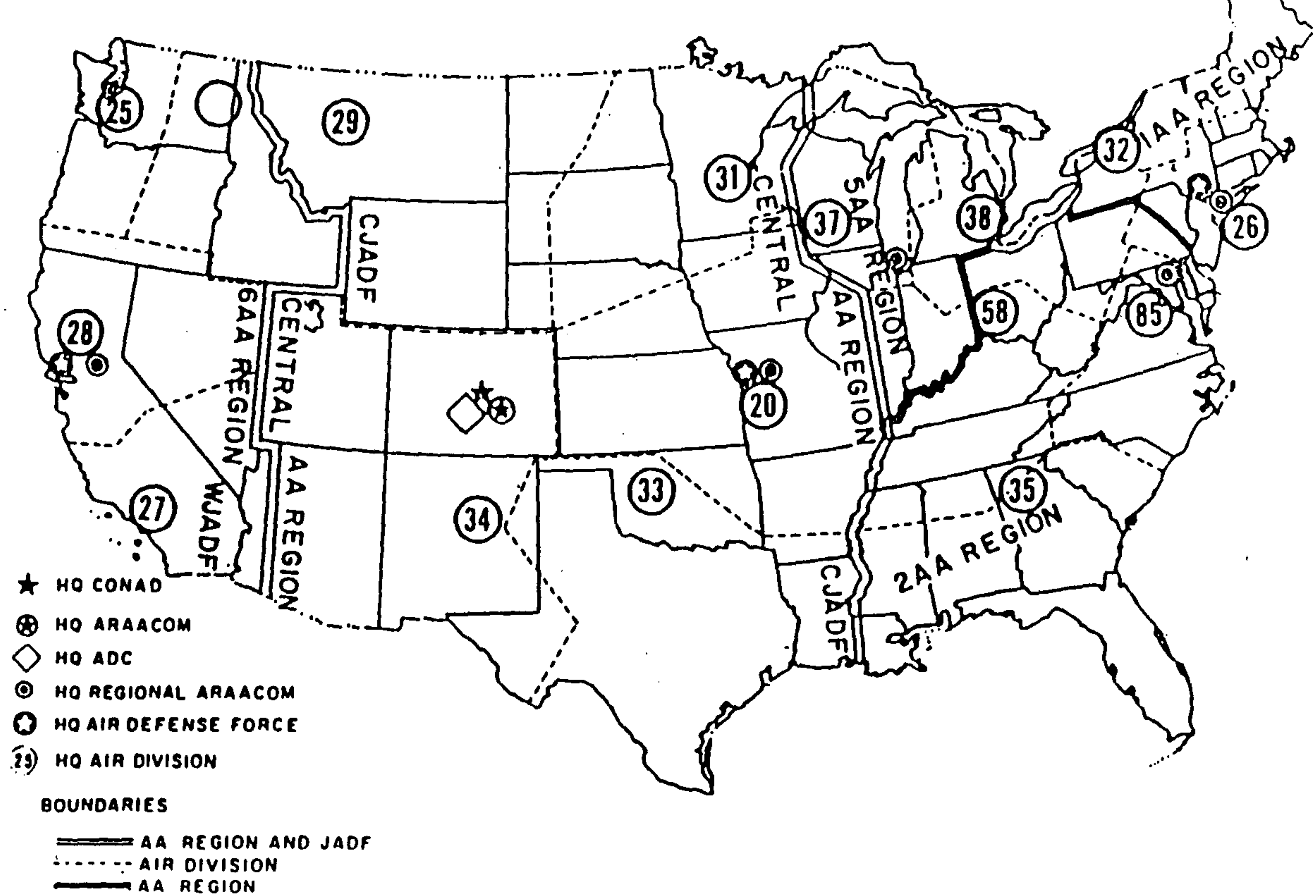
1 JULY 1955



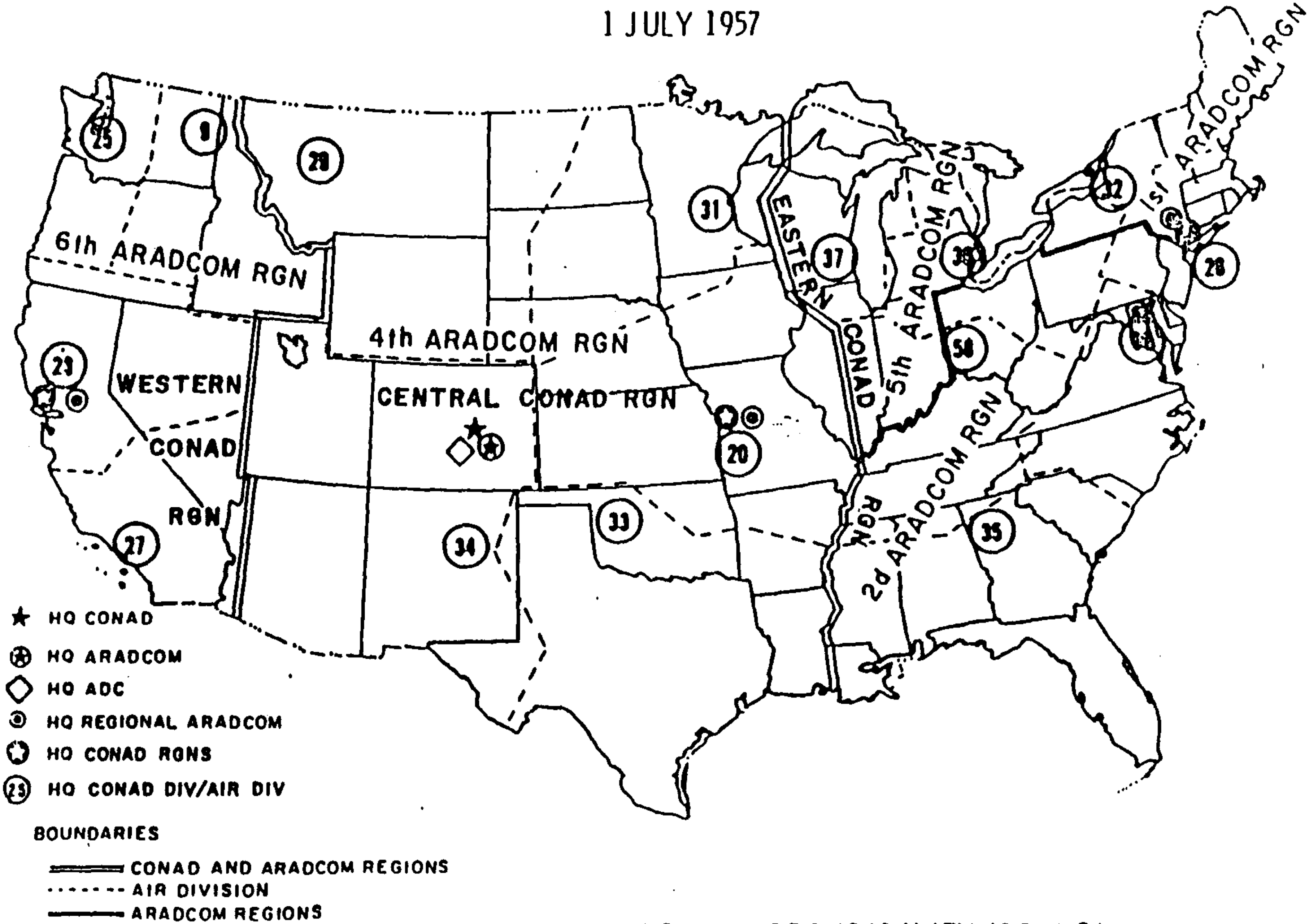
HEADQUARTERS AND AREAS OF RESPONSIBILITY (CONUS)

9 0 1 2 9 7 5 1 3 8 6

1 JULY 1956

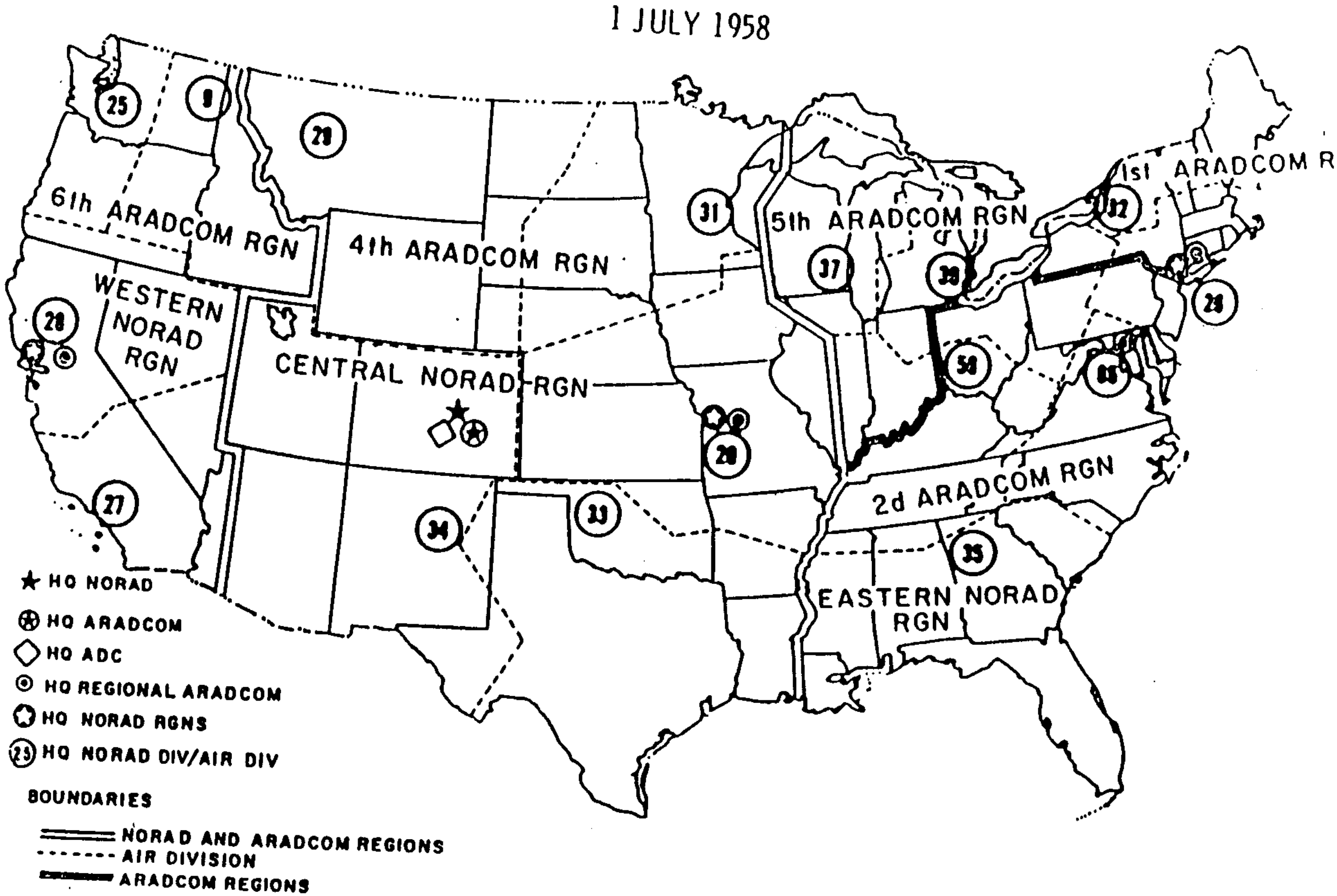


HEADQUARTERS AND AREAS OF RESPONSIBILITY (CONUS)



HEADQUARTERS AND AREAS OF RESPONSIBILITY (CONUS)

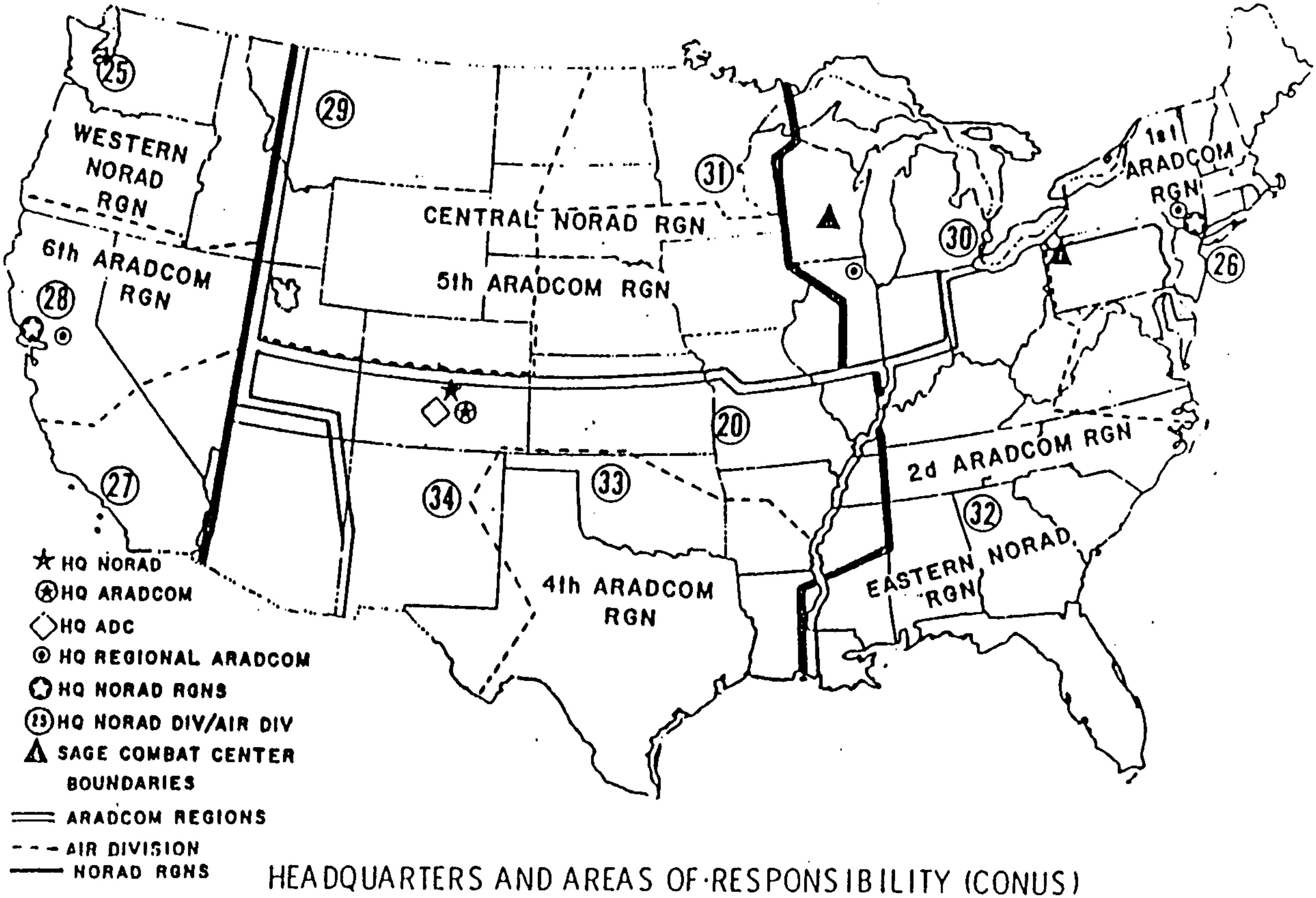
9 3 1 2 9 2 5 1 8 8 8



HEADQUARTERS AND AREAS OF RESPONSIBILITY (CONUS)

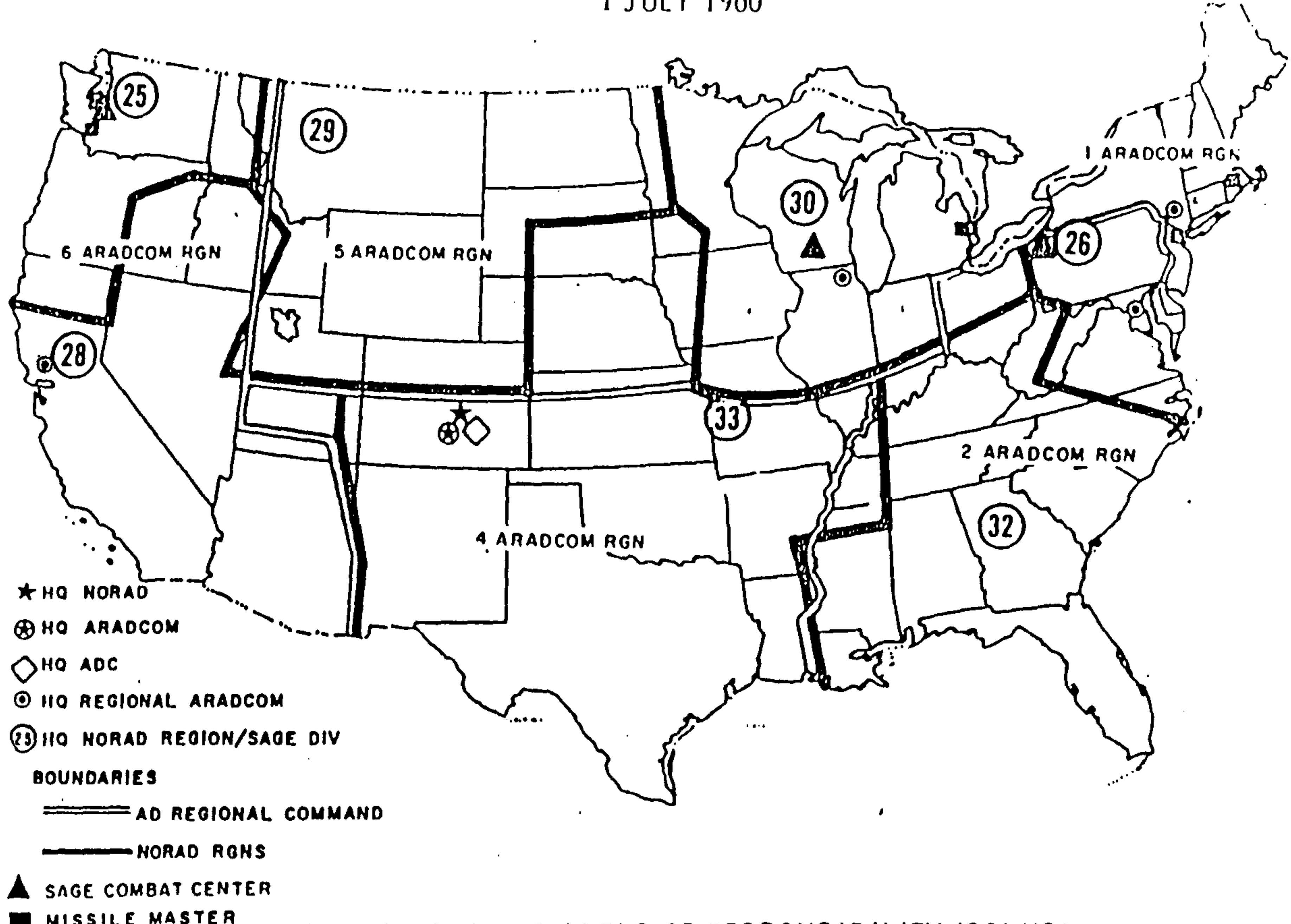
9 3 1 2 9 - 3 1 8 8 9

1 JULY 1959



HEADQUARTERS AND AREAS OF RESPONSIBILITY (CONUS)

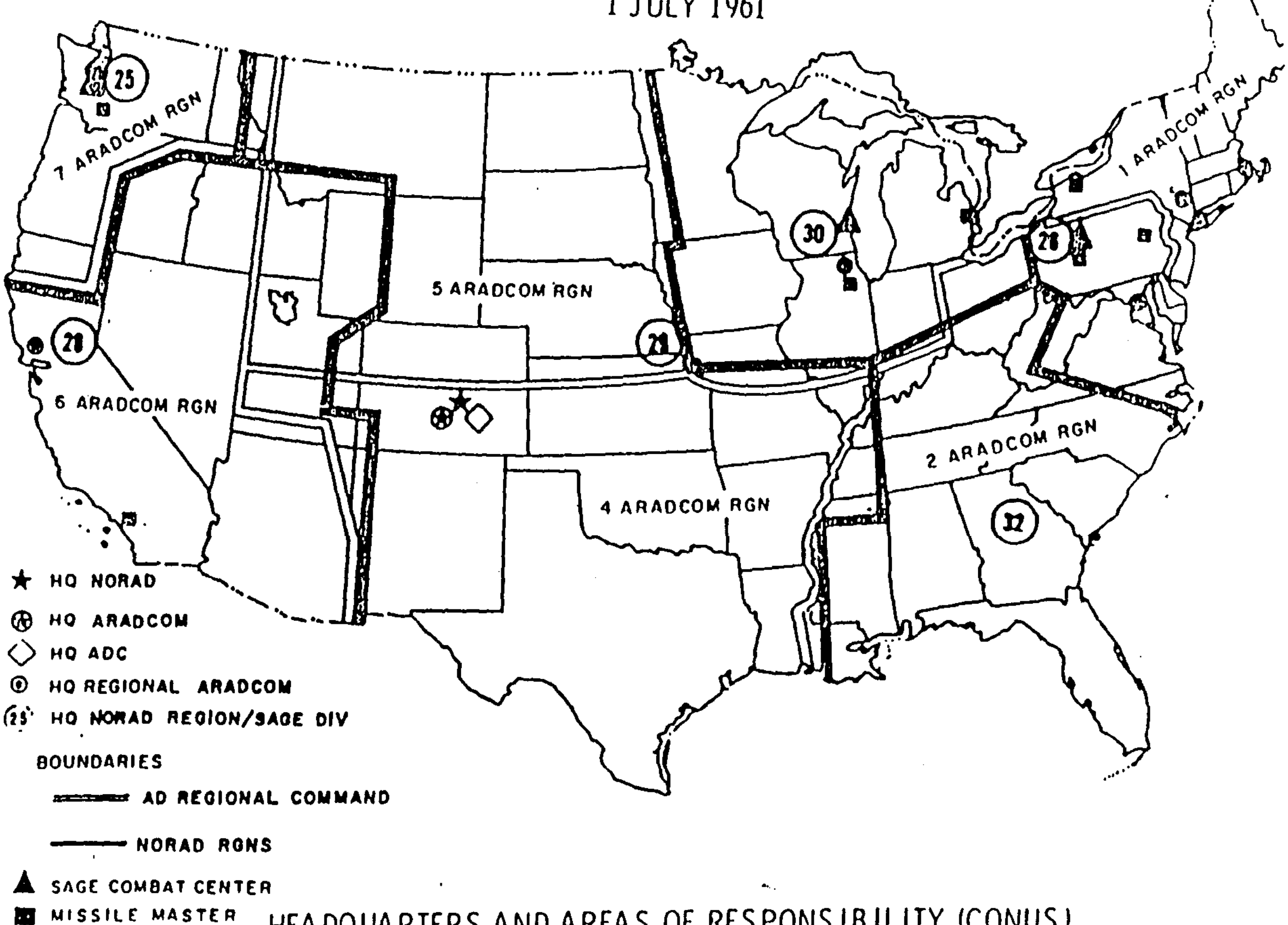
1 JULY 1960



HEADQUARTERS AND AREAS OF RESPONSIBILITY (CONUS)

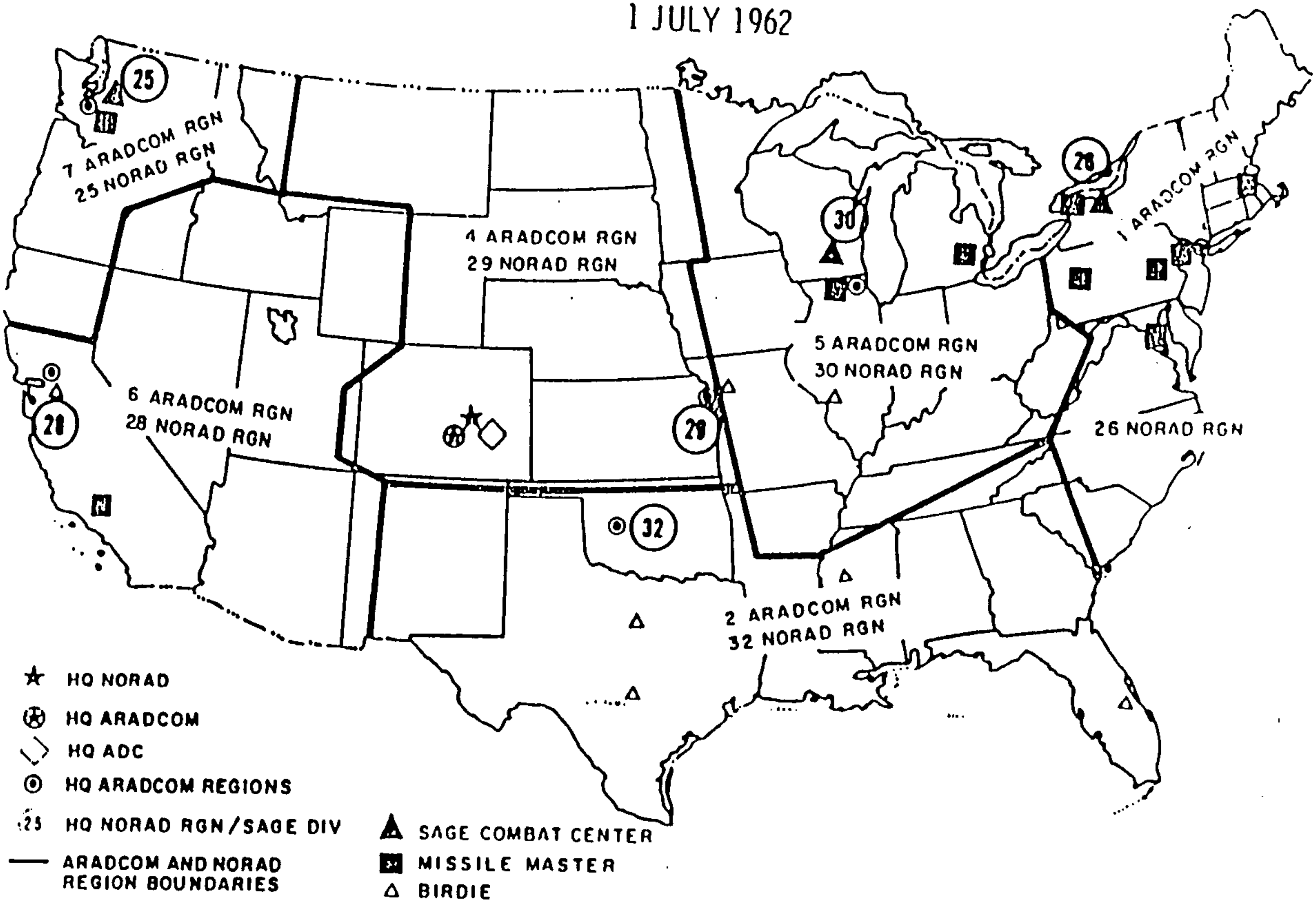
9 3 1 2 9 7 5 1 8 9 1

1 JULY 1961

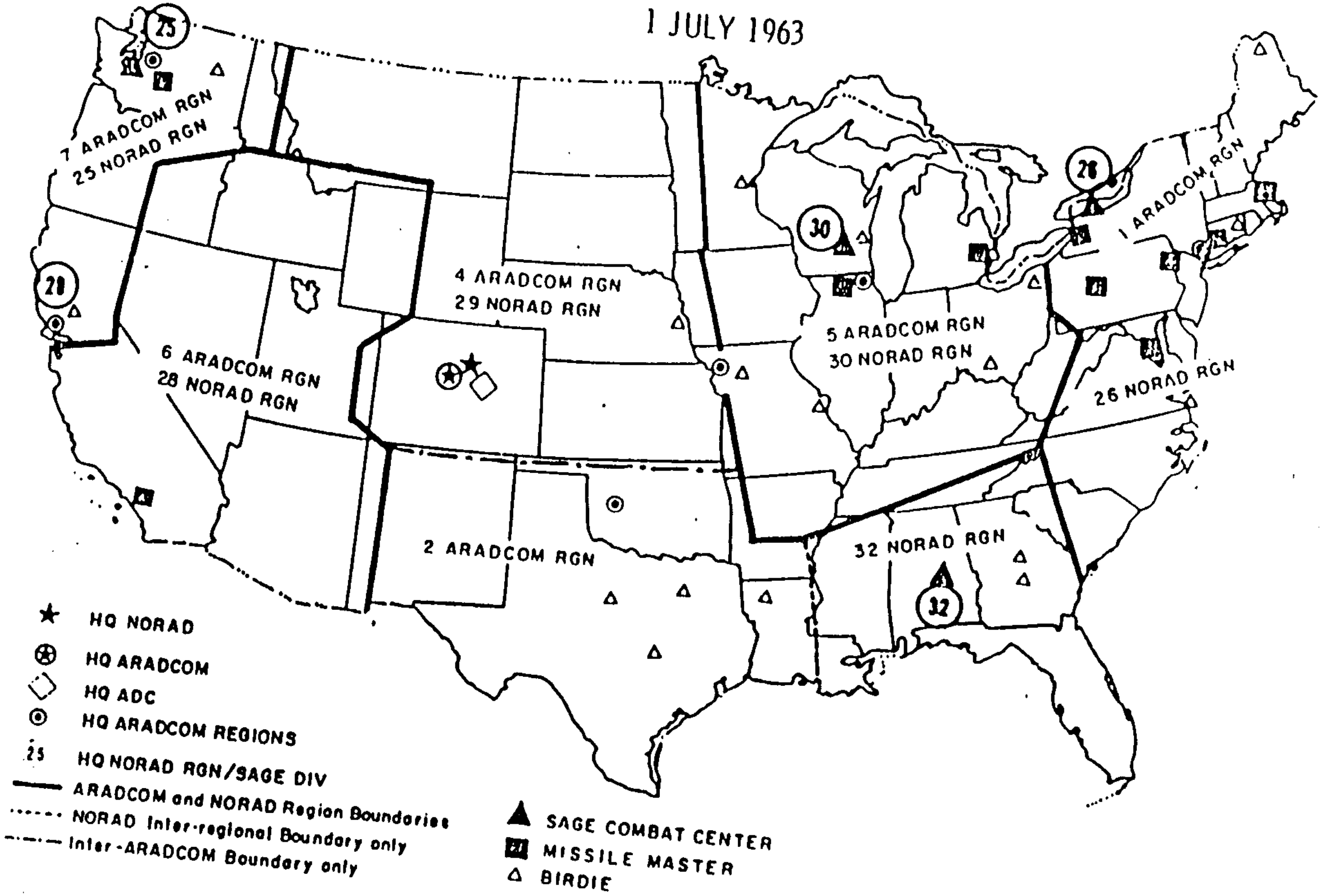


HEADQUARTERS AND AREAS OF RESPONSIBILITY (CONUS)

1 JULY 1962



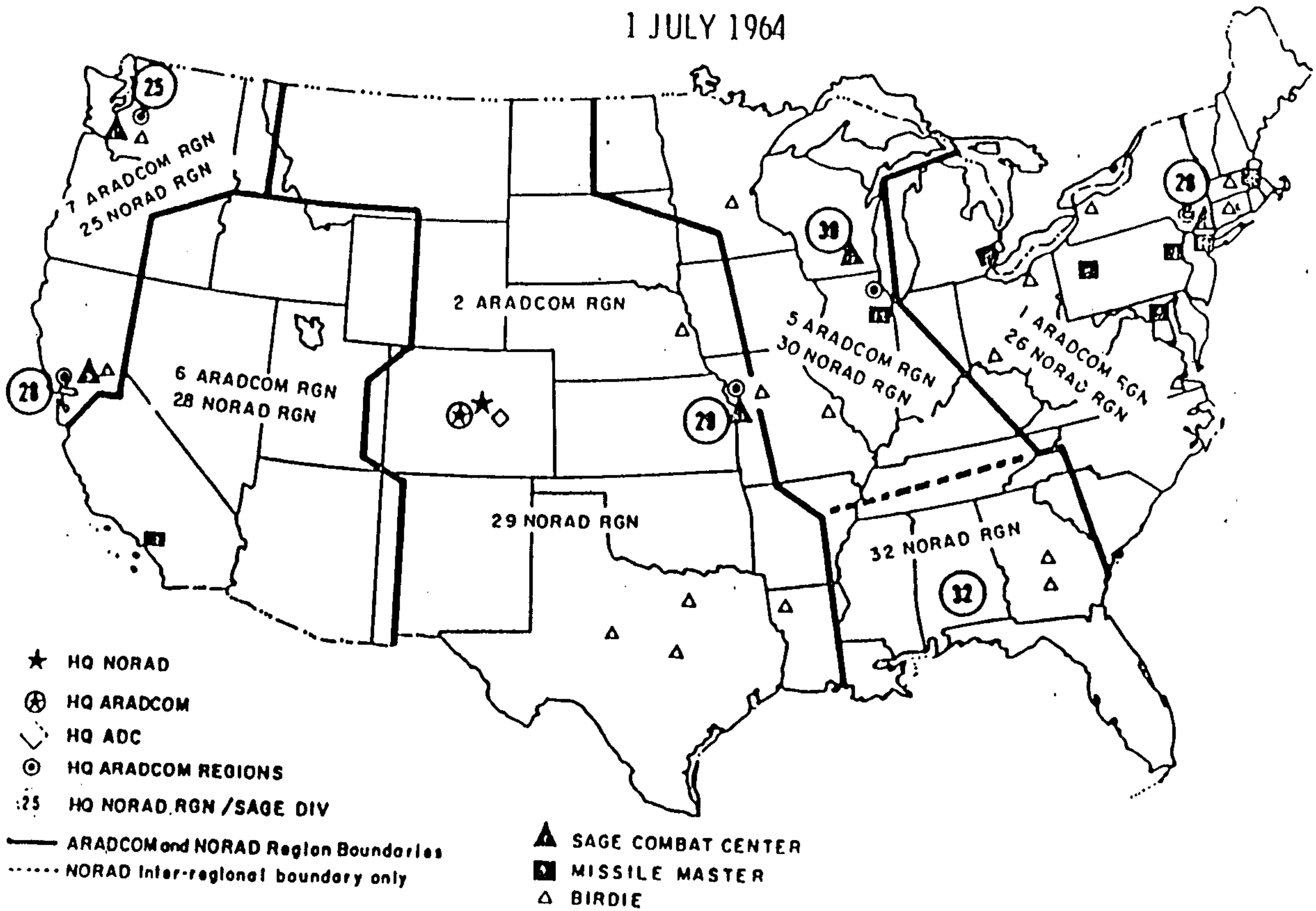
HEADQUARTERS AND AREAS OF RESPONSIBILITY (CONUS)



HEADQUARTERS AND AREAS OF RESPONSIBILITY (CONUS)

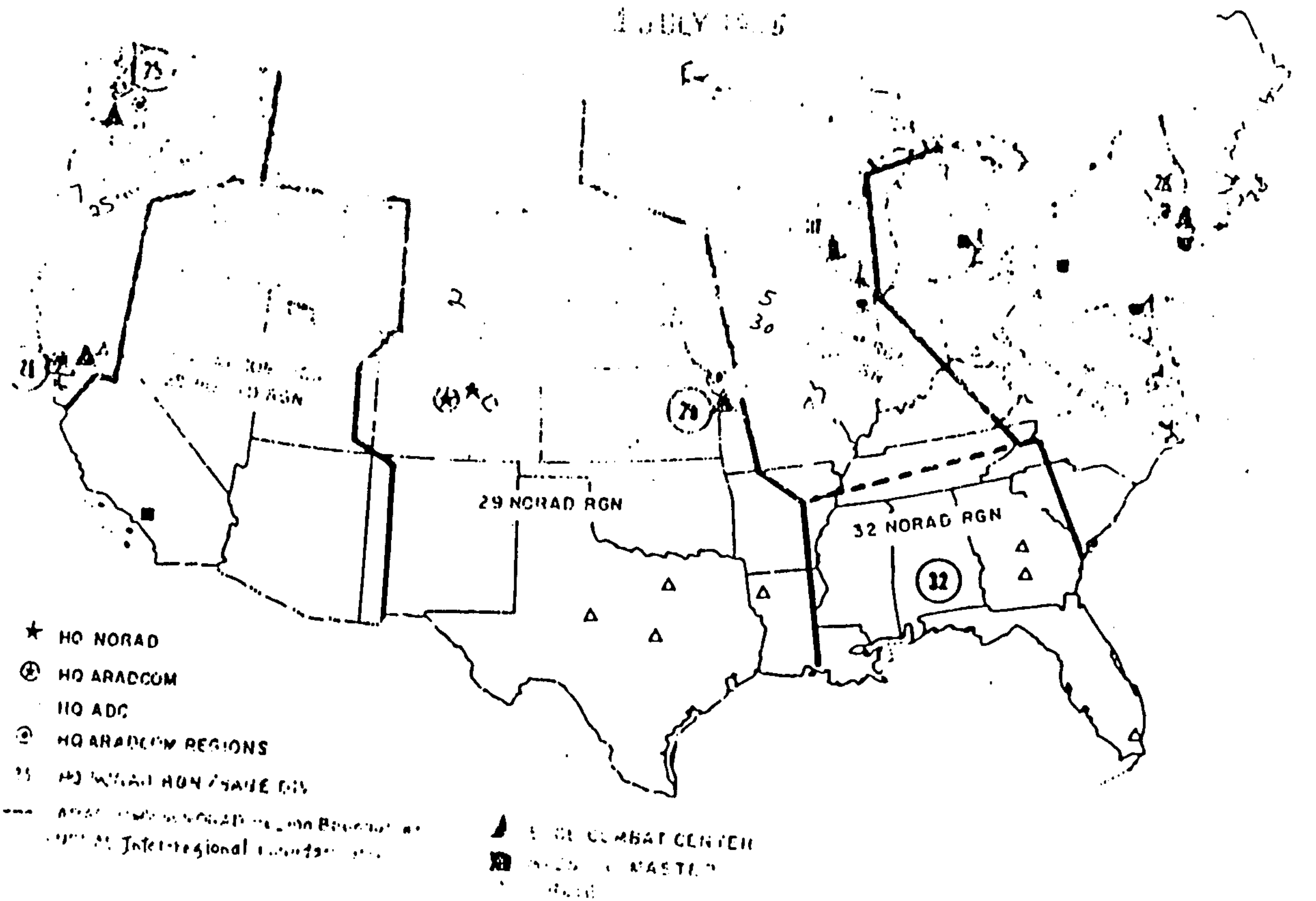
9 . 1 . 9 . . 1 . 9 4

1 JULY 1964



HEADQUARTERS AND AREAS OF RESPONSIBILITY (CONUS)

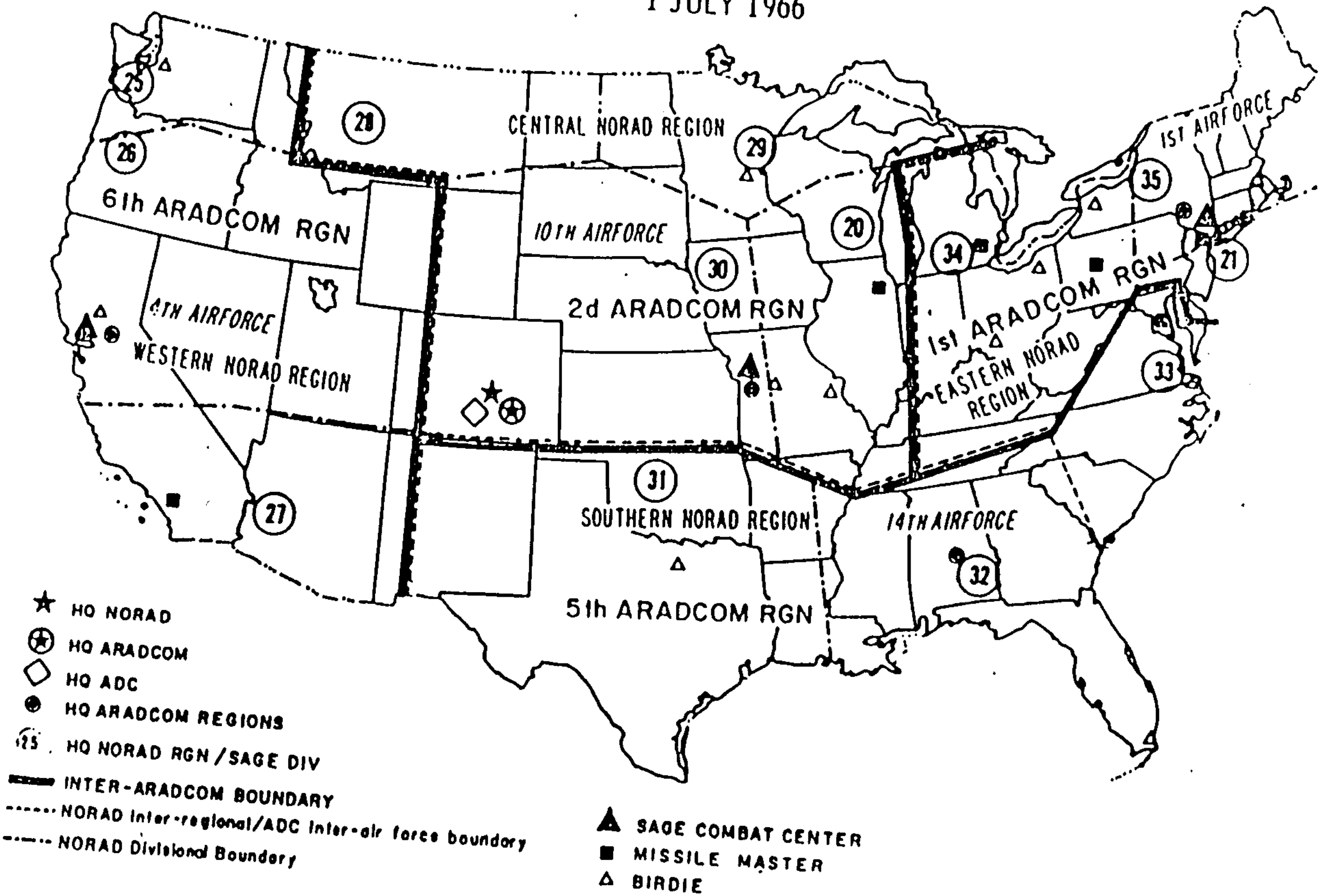
9 1 9 1 8 9 5



HEADQUARTERS AND AREAS OF RESPONSIBILITY (CONUS)

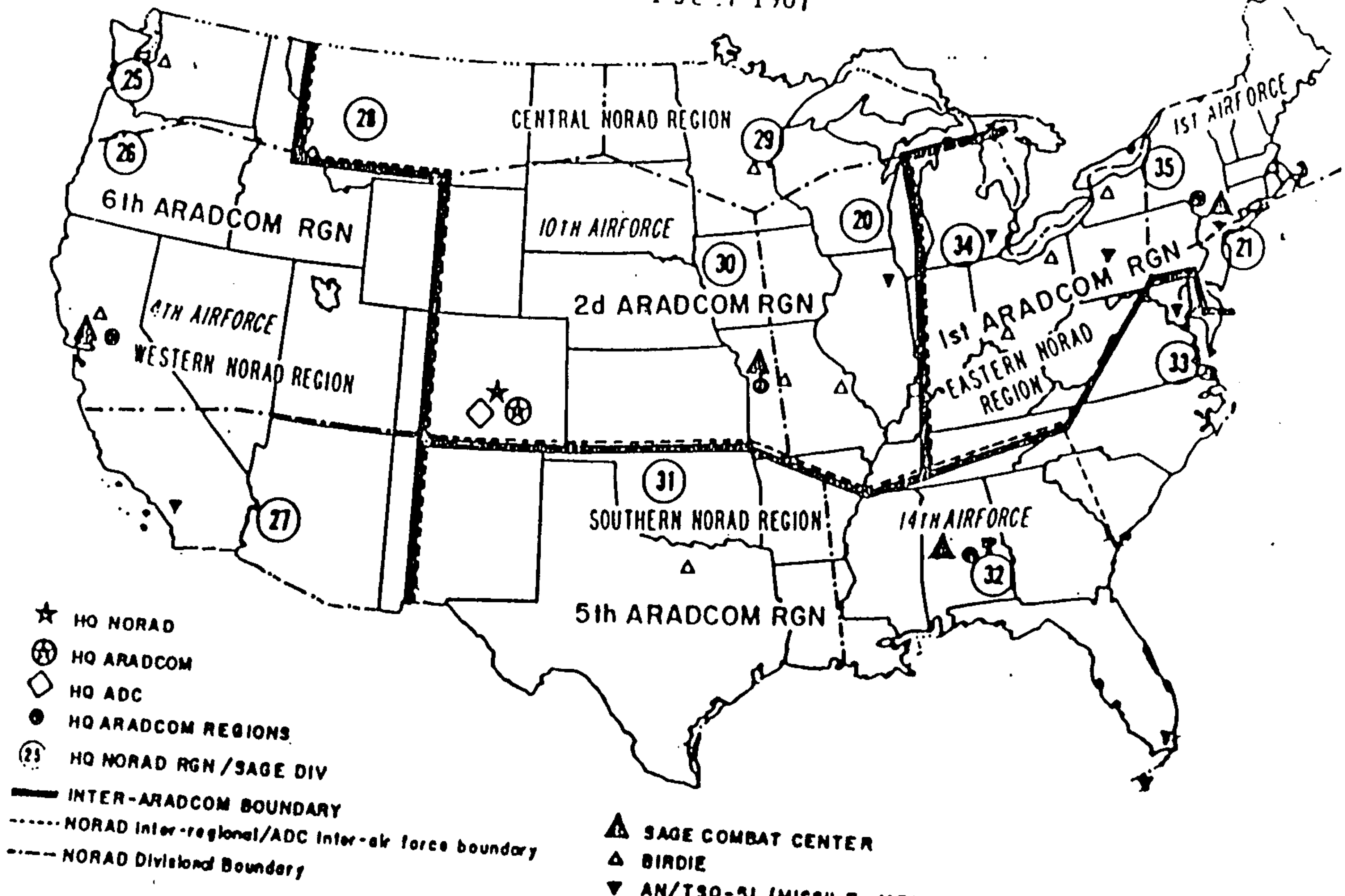
9 [illegible] 8 9 6

1 JULY 1966

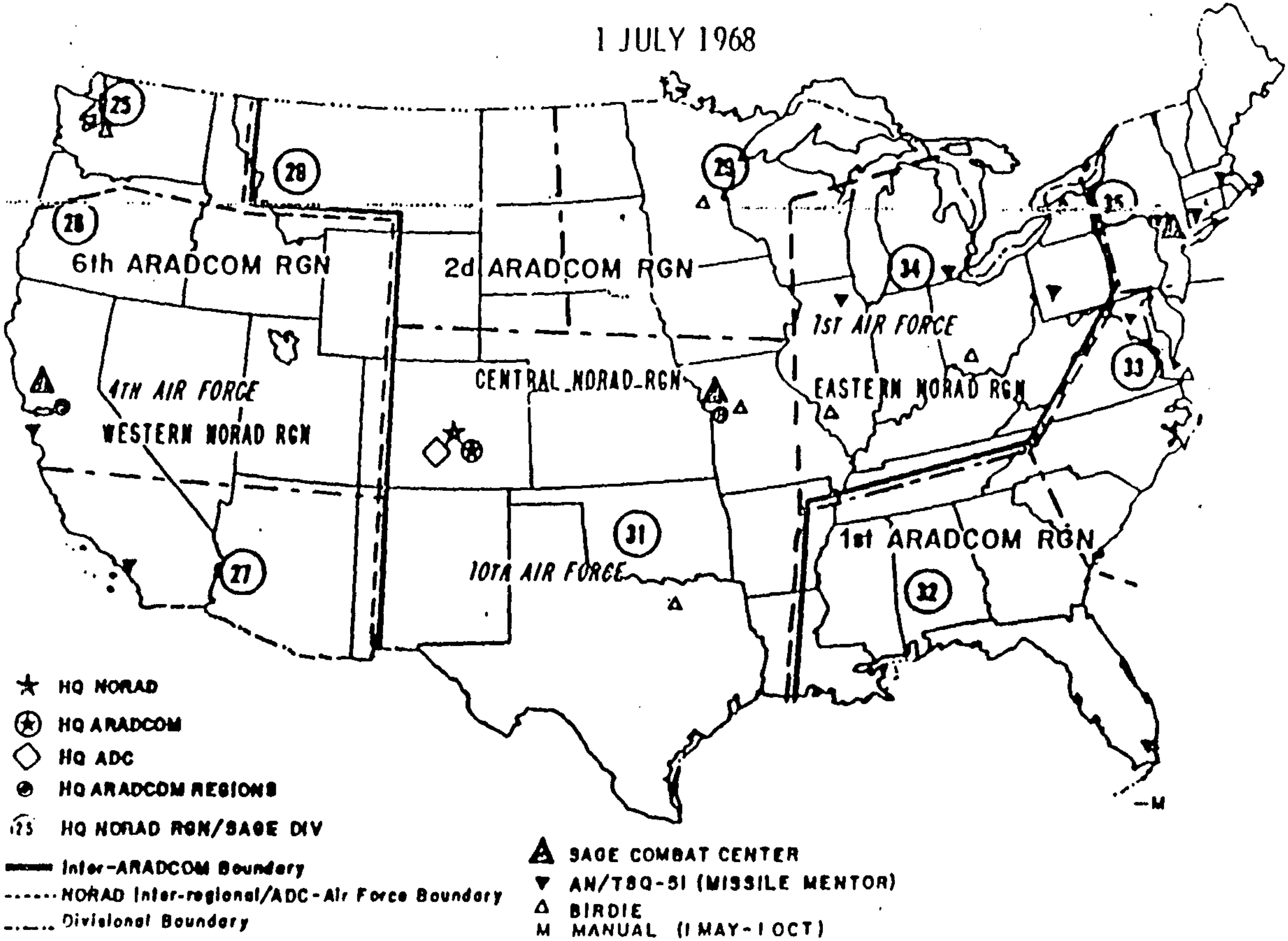


HEADQUARTERS AND AREAS OF RESPONSIBILITY (CONUS)

1 JULY 1967

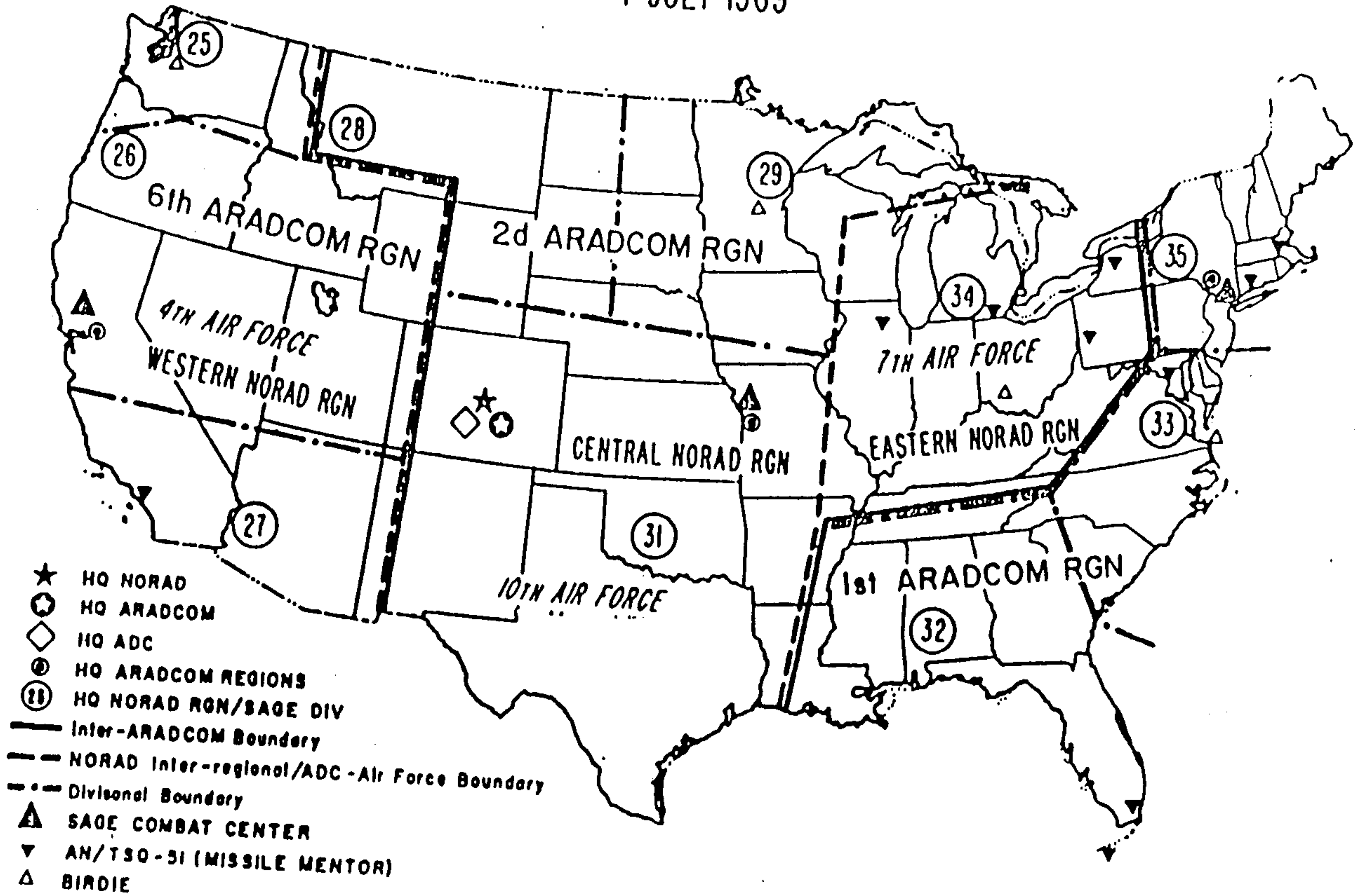


HEADQUARTERS AND AREAS OF RESPONSIBILITY (CONUS)



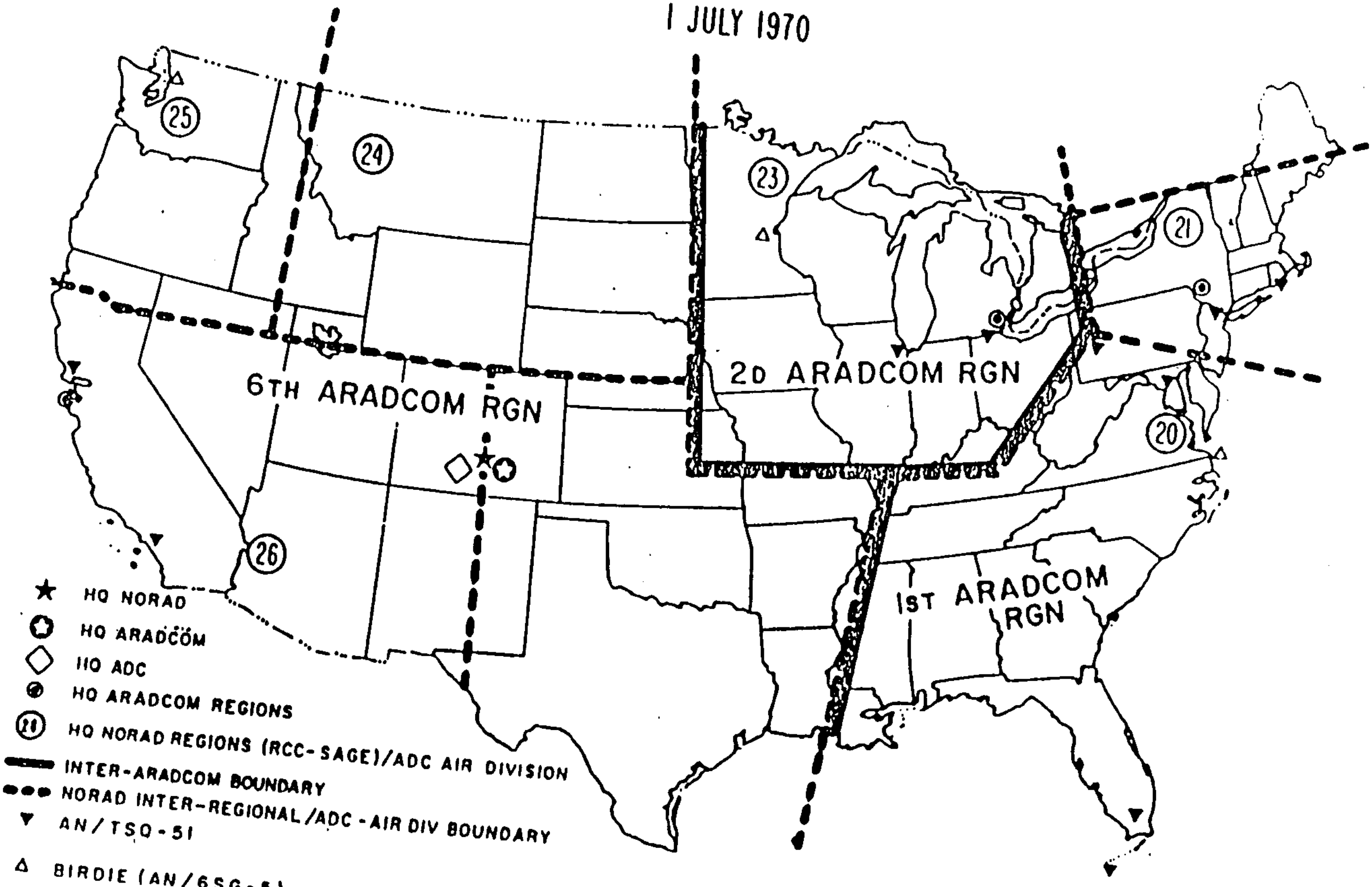
HEADQUARTERS AND AREAS OF RESPONSIBILITY (CONUS)

1 JULY 1969



HEADQUARTERS AND AREAS OF RESPONSIBILITY (CONUS)

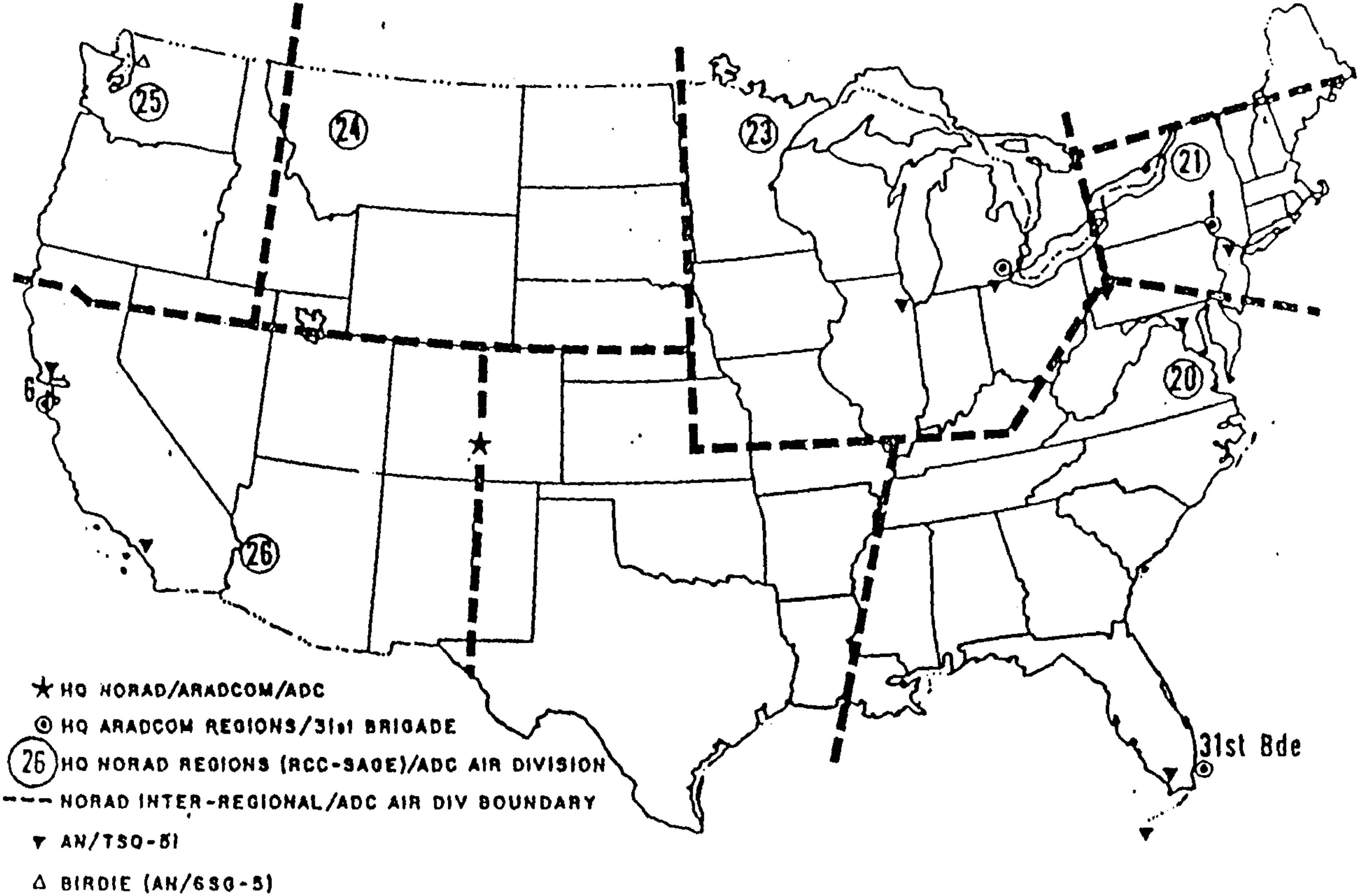
1 JULY 1970



HEADQUARTERS AND AREAS OF RESPONSIBILITY (CONUS)

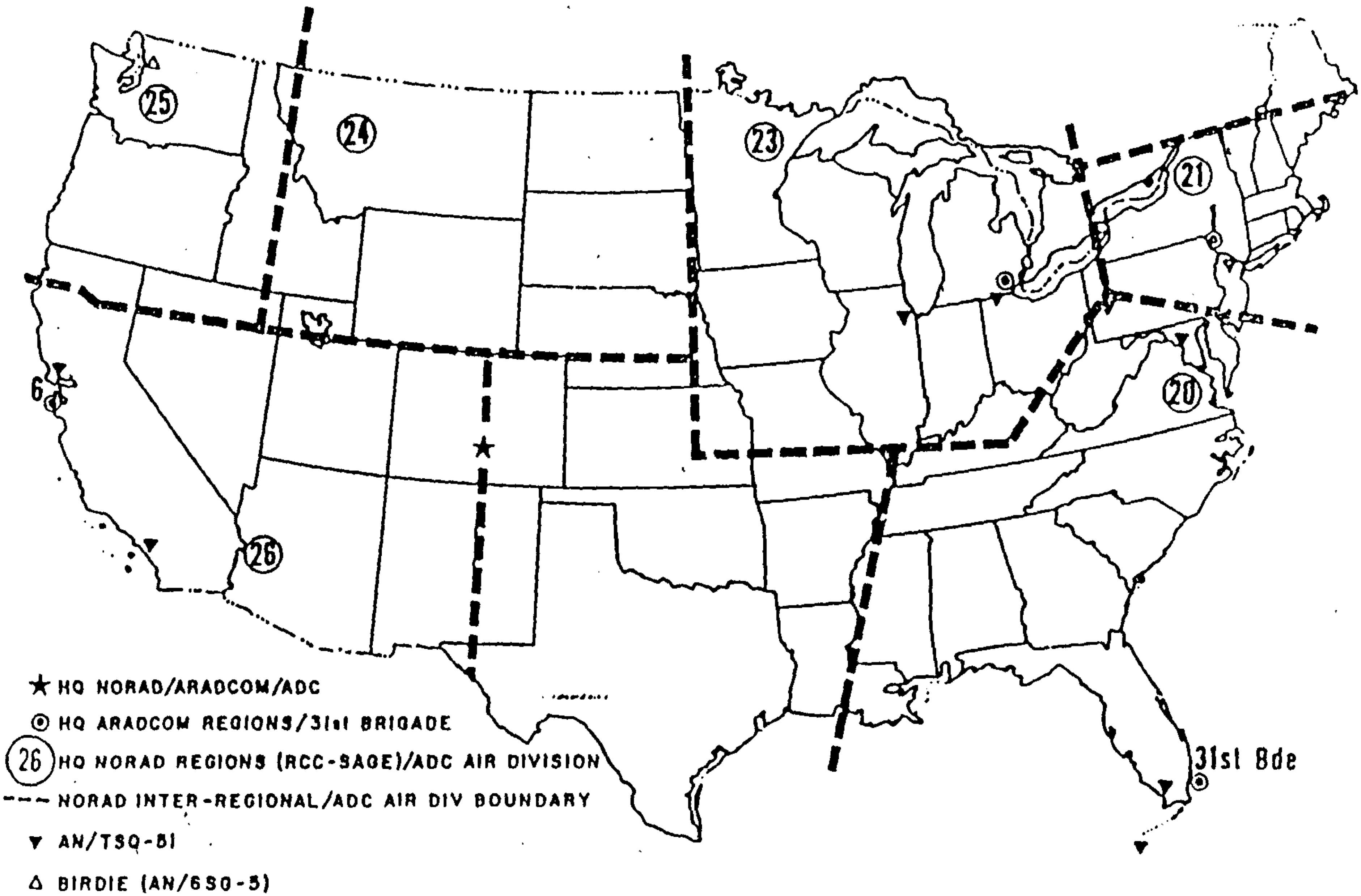
9 6 1 2 9 8 3 1 9 0 1

1 JULY 1971



HEADQUARTERS AND AREAS OF RESPONSIBILITY (CONUS)

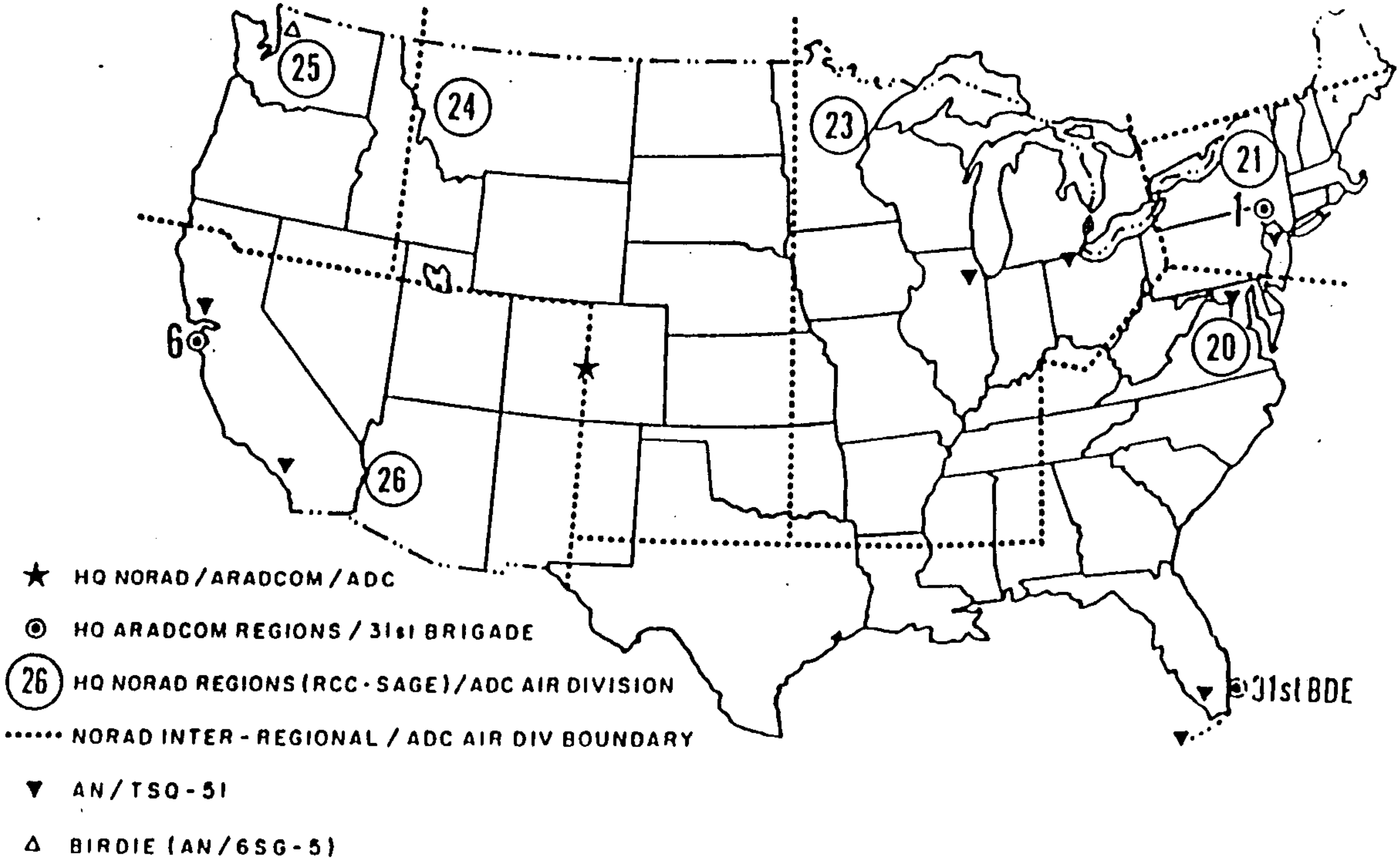
1 JULY 1972



HEADQUARTERS AND AREAS OF RESPONSIBILITY (CONUS)

9 3 1 2 9 7 5 1 9 0 3

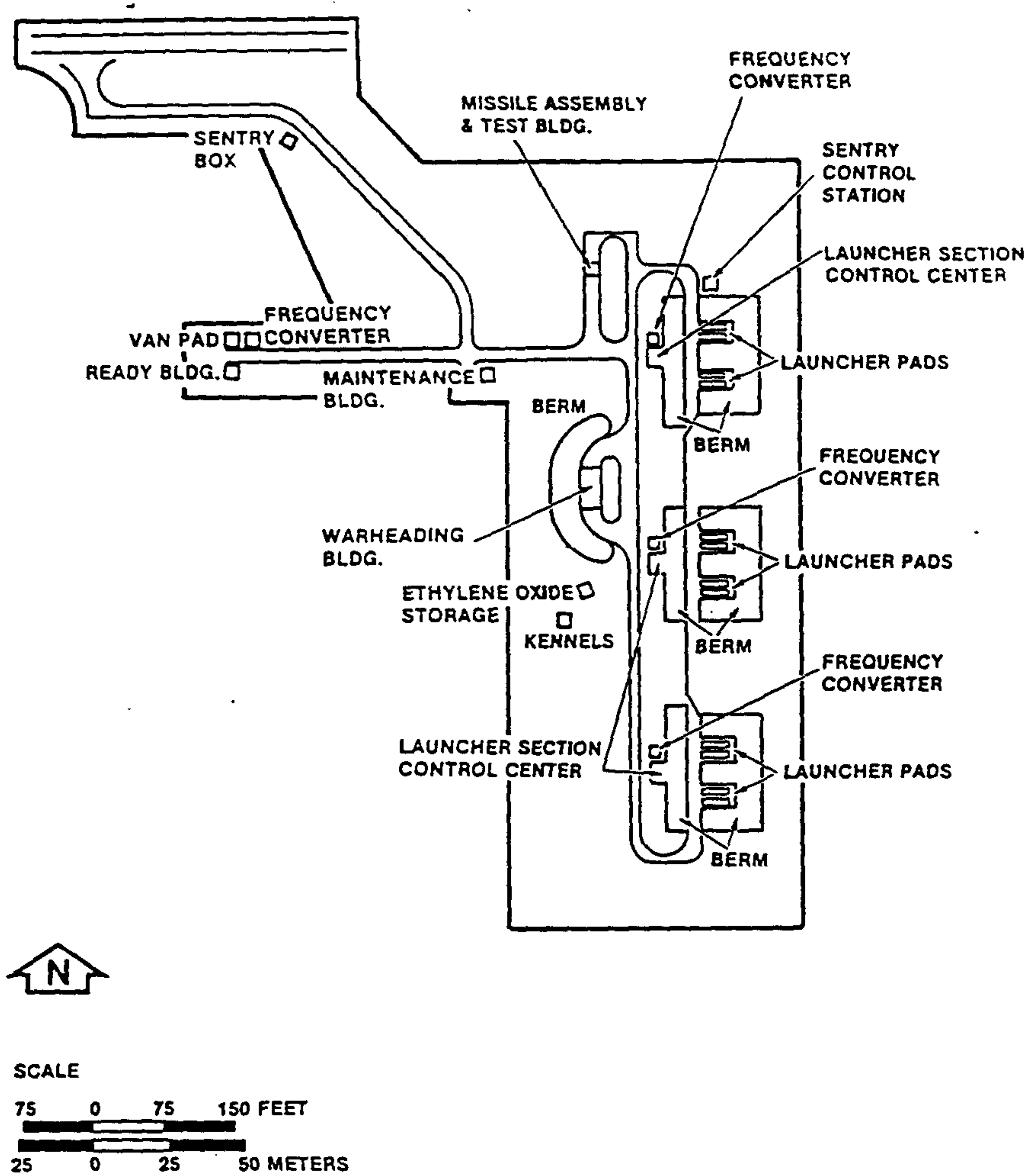
1 JULY 1973



HEADQUARTERS AND AREAS OF RESPONSIBILITY (CONUS)

APPENDIX D

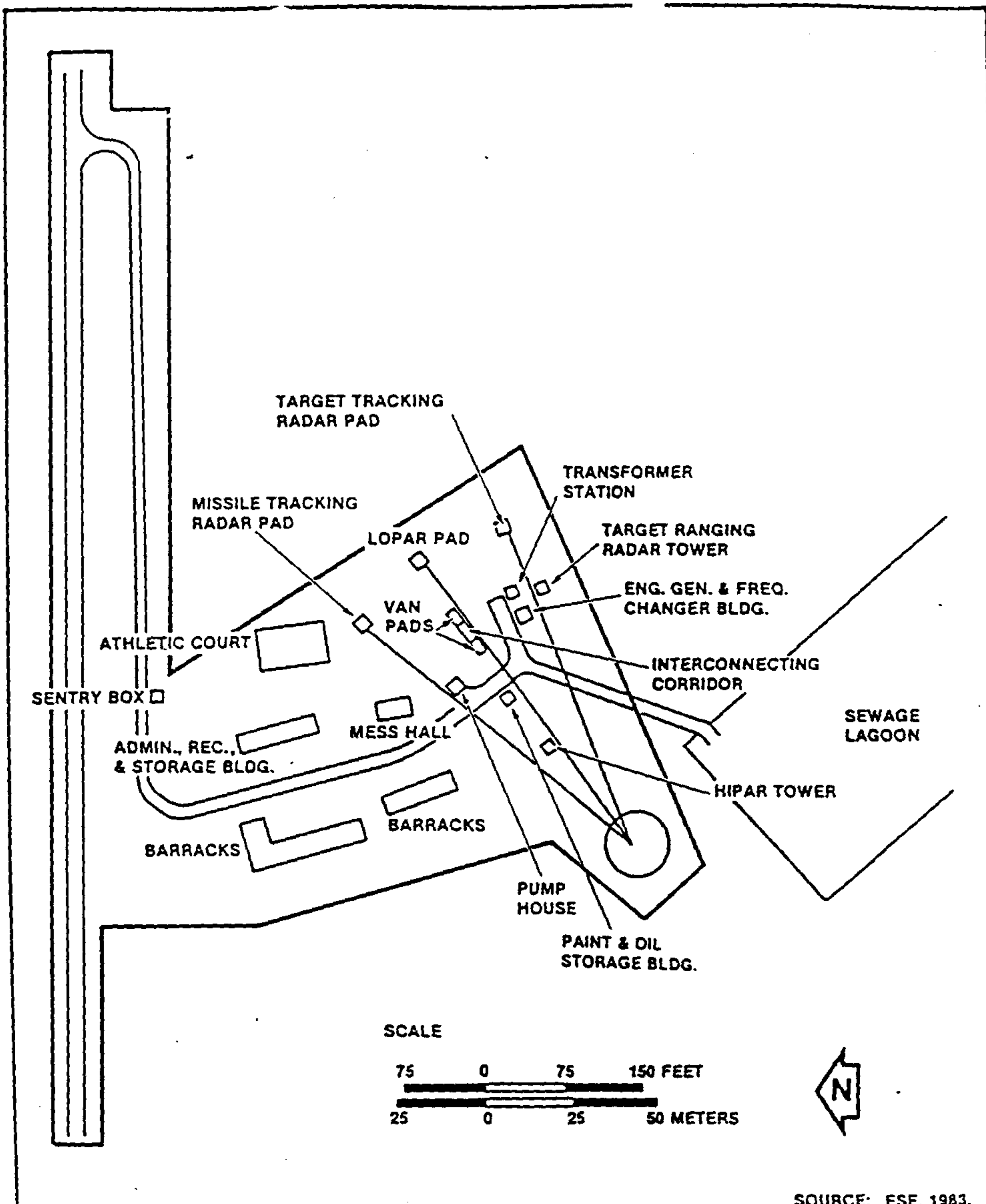
EXAMPLE NIKE SITE MAPS



SOURCE: ESE, 1983.

LAUNCH CONTROL AREA MAP
OFFUT AIR FORCE BASE (OF-10L),
COUNCIL BLUFFS, IOWA

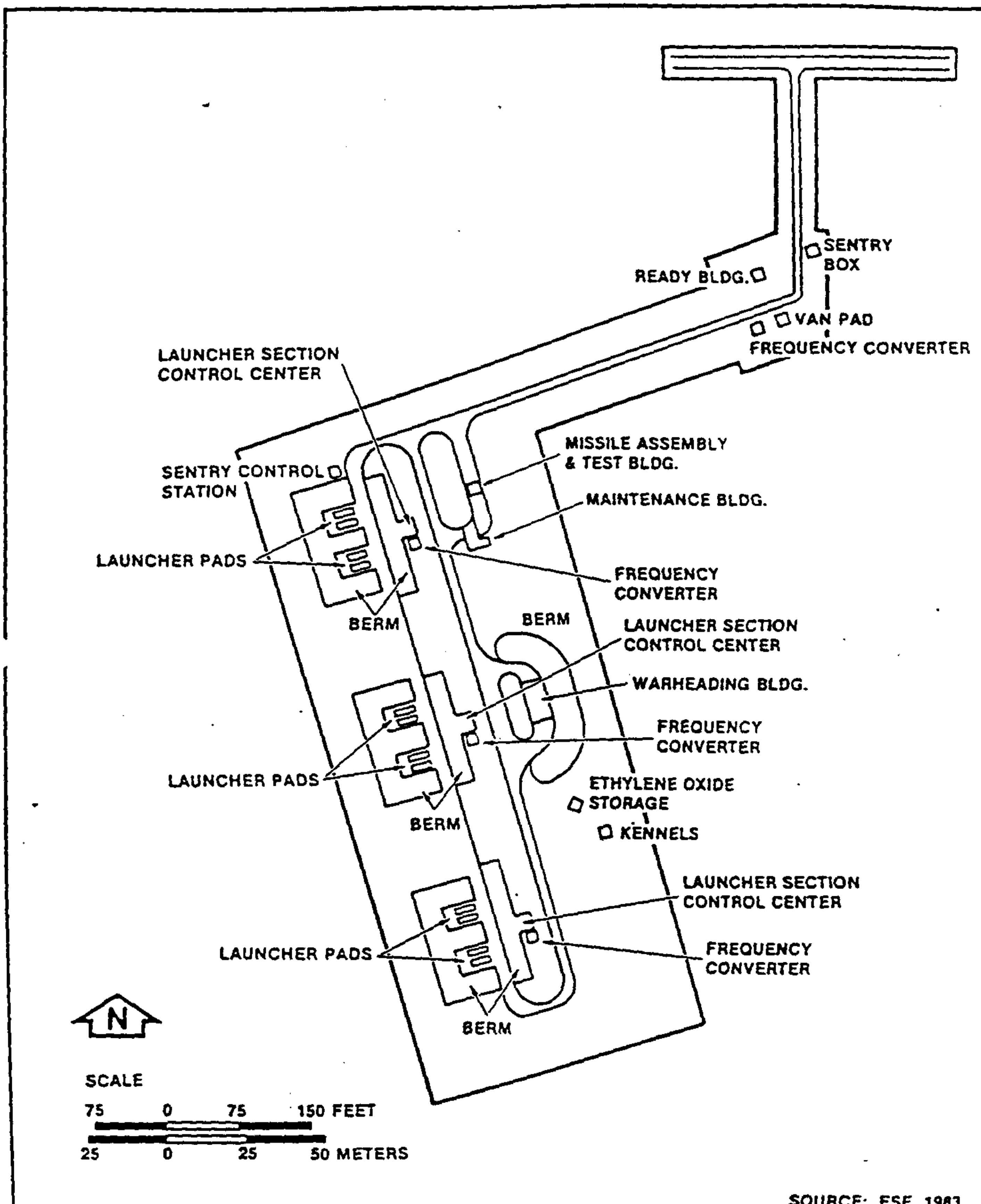
Prepared for:
U.S. Army Toxic and Hazardous Materials Agency
Aberdeen Proving Ground, Maryland



SOURCE: ESE, 1983.

BATTERY CONTROL AREA MAP
OFFUT AIR FORCE BASE (OF-10C),
COUNCIL BLUFFS, IOWA

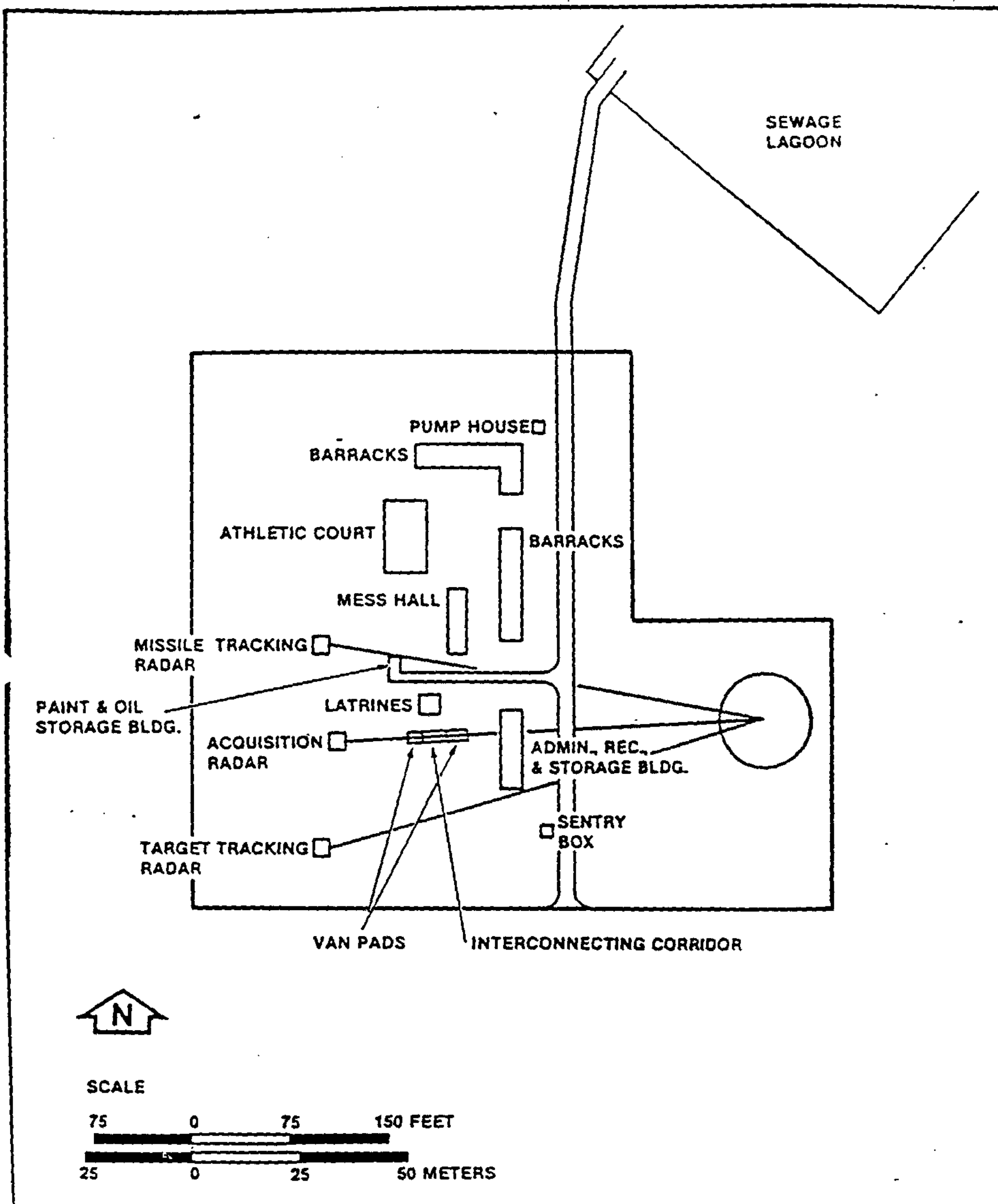
Prepared for:
U.S. Army Toxic and Hazardous Materials Agency
Aberdeen Proving Ground, Maryland



LAUNCH CONTROL AREA MAP
OFFUT AIR FORCE BASE (OF-60L),
PLATTSMOUTH, NEBRASKA

Prepared for:
U.S. Army Toxic and Hazardous Materials Agency
Aberdeen Proving Ground, Maryland

9 1 1 3 0 2 1 5 4 5 0 7



SOURCE: ESE, 1983.

BATTERY CONTROL AREA MAP
OFFUT AIR FORCE BASE (OF-60C),
PLATTSMOUTH, NEBRASKA

Prepared for:
U.S. Army Toxic and Hazardous Materials Agency
Aberdeen Proving Ground, Maryland